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THE EFFECTS OF US ARMY CHEMICAL PROTECTIVE CLOTHING ON SPEECH INTELLIGIBILITY, VISUAL FIELD, BODY MOBILITY AND PSYCHOMOTOR COORDINATION OF MEN

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This research was conducted to examine the effects of the Army's standard chemical protective (CP) clothing system on a number of aspects of a soldier's performance. Included in the research were tests of speech intelligibility, the visual field, body mobility, and psychomotor coordination. Twelve Army enlisted men participated in the speech intelligibility and the visual field testing and 11 Army enlisted men participated in the body mobility and the psychomotor coordination testing. In investigating body mobility and psychomotor coordination, the components of the CP system were tested individually, as well as in various combinations, in order to isolate the effects of each component and to determine the extent to which the components

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interact to affect performance. It was found that use of the CP mask and hood interfered with the wearer's ability to understand spoken words and to be understood when speaking. The mask also restricted the wearer's visual field. The impact of CP clothing on body mobility and psychomotor coordination varied as a function of the task being performed and the particular CP items, or combinations of items, being worn. Compared with the wearing of the Battle Dress Uniform, use of the complete chemical protective clothing system restricted head movements and had a deleterious effect on performance of tasks requiring visual-motor coordination or manual dexterity. The effects of the CP clothing on the aspects of performance included in this investigation, and on user acceptance, were considered in light of the material and design configurations of these clothing items.

SUMMARY

This research was conducted to examine the effects of the Army's standard chemical protective (CP) clothing system on a number of aspects of a soldier's performance. Included in the research were tests of speech intelligibility, the visual field, body mobility, and psychomotor coordination. In investigating body mobility and psychomotor coordination, the components of the CP system were tested individually, as well as in various combinations, in order to isolate the effects of each component and to determine the extent to which the components interact to affect performance.

The principal findings of this study as they relate to each component of the CP system were as follows:

1. CP Overgarment. Wearing of the overgarment restricted simple movements of the leg in the body's sagittal plane relative to use of a T-shirt and shorts and movement of the arm in the body's frontal plane relative to use of a T-shirt and shorts or to use of the Battle Dress Uniform coat and trousers. There was evidence as well that the CP overgarment interacted with other CP items to impede psychomotor coordination.

2. CP Mask. Words spoken by an individual wearing the mask were not understood as well as words spoken by an individual who was bareheaded. The mask also restricted the wearer's visual field, particularly in the nasal and the inferior regions, and limited head rotation and ventral flexion. In addition, the mask interacted with the CP gloves, and possibly other CP items, to impede psychomotor coordination.

3. CP Hood. Use of the hood and the mask interfered with the wearer's ability to understand spoken words. There were no indications that the hood restricted simple body movements or contributed toward impaired psychomotor capabilities.

4. CP Overboots. The overboots, per se, did not restrict simple body movements or result in significant reductions in psychomotor performance. However, the test subjects reported that the overboots increased the difficulty of executing a task that required coordinated movements of the legs and the feet.

5. CP Gloves. The gloves impaired manual dexterity capabilities and may also have interacted with other CP items to negatively affect performance of tasks requiring coordinated hand movements.

PREFACE

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TABLE OF CONTENTS

	Page
Summary	iii
Preface	iv
List of Illustrations	vii
List of Tables	viii
Introduction	1
Subjects	3
Clothing Items	5
Speech Intelligibility Testing	15
Purpose	15
Method	15
Subjects	15
Clothing conditions	15
Apparatus and procedure	15
Results and Discussion	17
Visual Field Testing	20
Purpose	20
Method	20
Subjects	20
Clothing conditions	20
Apparatus and procedure	20
Results and Discussion	23
Body Mobility and Psychomotor Coordination Testing	27
Purpose	27
Method	30
Subjects	30
Tasks and questionnaire	30
Procedure	33
Investigation I. Comparison of MOPP IV With the BDU	34
Clothing conditions and tasks	34
Results	35
Discussion	39
Investigation II. Comparison of the CP Overgarment With Other Torso Clothing	39
Clothing conditions and tasks	39
Results	39
Discussion	43

TABLE OF CONTENTS (cont'd)

	Page
Body Mobility and Psychomotor Coordination Testing (cont'd)	
Investigation III. Individual and Combined Effects of CP Items Exclusive of the CP Overgarment	48
Clothing conditions and tasks	48
Results	49
Discussion	65
Investigation IV. Effects of Wearing CP Items With the CP Overgarment	68
Clothing conditions and tasks	68
Results	70
Discussion	88
Investigation V. Comparison of MOPP Levels	93
Clothing conditions and tasks	93
Results	95
Discussion	101
General Discussion	103
Conclusions and Recommendations	107
References	109
Appendices	
A. Body Measurement Techniques	113
B. Photographs of CP Clothing Items	119
C. Modified Rhyme Test Instructions to Listener, Word Lists, and Answer Sheets	125
D. Descriptions and Instructions for Body Mobility and Psychomotor Tasks	139
E. Clothing and Performance Questionnaire	155

LIST OF ILLUSTRATIONS

Figure		Page
1a.	Mean Percentage Correct on the Modified Rhyme Test as a Function of Headwear Condition of the Talker and the Listener.	19
1b.	Mean Percentage Correct on the Modified Rhyme Test for Each Experimental Condition.	19
2.	Visual Perimetry Setup.	21
3.	Mean Visual Field of Both Eyes Combined for the Bare-Head and the Mask Conditions.	26
4.	Mean Score on Standing Trunk Flexion as a Function of Shorts and Mask.	52
5.	Mean Scores on Arm Mobility Tasks as a Function of Shorts and Mask.	53
6.	Mean Scores on Leg Mobility Tasks as a Function of Shorts and Overboots.	54
7.	Mean Scores on Head Mobility Tasks as a Function of Shorts and Mask.	55
8.	Mean Scores on Manual Dexterity Tasks as a Function of Shorts, Mask, and Gloves.	56
9.	Mean Scores on Visual-Motor Coordination Tasks as a Function of Shorts, Mask, and Overboots or Gloves.	57
10.	Mean Score on Standing Trunk Flexion as a Function of Overgarment, Mask, Overboots, and Gloves.	73
11.	Mean Score on Upper Arm Abduction as a Function of Overgarment, Mask, Overboots, and Gloves.	74
12.	Mean Score on Upper Arm Forward Extension as a Function of Overgarment, Mask, Overboots, and Gloves.	75
13.	Mean Score on Upper Arm Backward Extension as a Function of Overgarment, Mask, Overboots, and Gloves.	76
14.	Mean Scores on Leg Mobility Tasks as a Function of Overgarment and Overboots.	77
15.	Mean Scores on Head Mobility Tasks as a Function of Overgarment and Mask.	78
16.	Mean Scores on Manual Dexterity Tasks as a Function of Overgarment, Mask, and Gloves.	79
17.	Mean Scores on Visual-Motor Coordination Tasks as a Function of Overgarment, Mask, and Overboots or Gloves.	80

LIST OF TABLES

Tables	Page
1. Selected Body Dimensions of the Subjects ($11 \leq N \leq 12$)	3
2. Chemical Protective Items Used in Study	5
3. Finished Measurements (in cm) of the Battle Dress Uniform	6
4. Size Prediction Chart (in cm) for the Battle Dress Uniform	8
5. Finished Measurements (in cm) of the CP Overgarment	10
6. Size Prediction Chart (in cm) for the CP Overgarment	11
7. Mean Dimensions of Subjects for Each Overgarment Size	12
8. Mean Dimensions (in cm) of Subjects for Each Mask Size	13
9. Mean Dimensions (in cm) of Subjects for Each Glove Size	14
10. Analysis of Variance of Modified Rhyme Test Data	17
11. Mean Visual Field (in degrees) of Each Eye for the Bare-Head and the Mask Conditions	24
12. Mean Scores for Body Mobility and Psychomotor Tasks Under BDU and MOPP IV Conditions	36
13. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under BDU and MOPP IV Conditions	37
14. Median Ratings of Bipolar Dimensions for Body Mobility and Psychomotor Tasks Under BDU and MOPP IV Conditions	38
15. Mean Scores for Body Mobility and Psychomotor Tasks Under Shorts, BDU, and Overgarment Conditions	40
16. Median Ratings of Torso Clothing Design Characteristics for Body Mobility and Psychomotor Tasks Under Shorts, BDU, and Overgarment Conditions	42
17. Median Ratings of Bipolar Dimensions for Body Mobility and Psychomotor Tasks Under Shorts, BDU, and Overgarment Conditions	44
18. Tasks Performed Under Each Clothing Condition Included in Investigation III	50
19. Mean Scores for Body Mobility and Psychomotor Tasks Under Each Condition in Which Shorts and CP Items Were Worn	51

LIST OF TABLES (cont'd)

Tables	Page
20. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under Each Condition in Which Shorts and CP Items Were Worn	59
21. Median Ratings of Mask Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn with Shorts	61
22. Median Ratings of Hood Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With Shorts	62
23. Median Ratings of Overboot Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Overboots Were Worn With Shorts	63
24. Median Ratings of Glove Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Gloves Were Worn With Shorts	64
25. Tasks Performed Under Each Clothing Condition Included in Investigation IV	69
26. Mean Scores for Body Mobility and Psychomotor Tasks Under Each Condition in Which the Overgarment and Other CP Items Were Worn	71
27. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under Each Condition in Which the Overgarment and Other CP Items Were Worn	82
28. Median Ratings of Mask Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With the Overgarment	84
29. Median Ratings of Hood Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With the Overgarment	85
30. Median Ratings of Overboot Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Overboots Were Worn With the Overgarment	86
31. Median Ratings of Glove Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Gloves Were Worn With the Overgarment	87

LIST OF TABLES (cont'd)

Tables	Page
32. Tasks Performed Under Each MOPP Level in Investigation V	94
33. Mean Scores for Body Mobility and Psychomotor Tasks Under Each MOPP Level	96
34. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under Each MOPP Level	98
35. Median Ratings of Bipolar Dimensions for Body Mobility and Psychomotor Tasks Under Each MOPP Level	100

THE EFFECTS OF US ARMY CHEMICAL PROTECTIVE CLOTHING ON SPEECH INTELLIGIBILITY, VISUAL FIELD, BODY MOBILITY AND PSYCHOMOTOR COORDINATION OF MEN

INTRODUCTION

Degradation in the performance of the individual soldier attributable to the wearing of chemical protective (CP) items is a critical factor in determining the likelihood of successful outcomes of missions in a chemical warfare environment. A number of investigations have been carried out to assess the nature and the extent of such degradations.[1,2,3,4,5] It was found in these studies that physiological stress, in particular heat stress, and the extreme environmental conditions that elicit the physiological responses can be major factors contributing to performance degradation in protective attire. The insulation and the low moisture permeability of the chemical protective clothing system limit the body's normal heat-dissipating mechanisms, most markedly the evaporation of sweat. Core and skin temperatures rise, reflecting the accumulation of heat, as does heart rate to support the added demand for cutaneous perfusion.[6] Depending upon environmental conditions and work rates, the soldier can become a heat casualty within 30 to 90 minutes.[7] Such a loss of troops diminishes the effectiveness of the military unit as does the alternative of pacing work so that the soldier has frequent rest intervals.

Because of the devastating effects that the protective clothing system may have on the physiological status of the individual soldier and thus on mission performance, much of the research associated with protection of the individual soldier in a chemical warfare environment has focused on determining tolerance times as a function of work rates and ambient conditions,[7] evaluating the effectiveness of various protective materials in minimizing the heat load,[8] and investigating the use of cooling devices, worn in conjunction with the chemical protective system, in alleviating thermal stress.[9] Although physiological stress is a major concern, the findings from a number of field studies have suggested that the protective items themselves, independent of the thermal burden they represent, can interfere with performance of mission-related duties. For example, reports by Whitley et al.[5] and the US Army Combat Developments Experimentation Command[2,3,4,10] have indicated that wearing chemical protective items can result in mobility constraints, degraded manual dexterity, impaired visual-motor coordination. and sensory deficits, such as obstructed vision. These findings were based on subjective assessments of the effects of the protective items on performance, and little work has been done to quantify the direct, mechanical effects of the items on sensory-motor abilities.

In addition, because physiological stress was often an element in the scenarios that have been the test bed for studies of the effects of chemical protective items, it has been difficult to identify the relative contributions that stress factors and factors associated with the material and design characteristics of the items make to performance degradation. For example, soldiers participating in field studies have reported that the protective mask, because of its lens design, interferes with vision.[3,4] In the same context, it has been reported that the mask induces sweating and that the sweat blocks vision.[3,4] Thus, in situations in which there is a thermal burden, it is

difficult to determine the extent to which some design feature of a protective item, rather than the responses of the body to stress, is responsible for degraded performance.

The purpose of the present research was to obtain data on the effects that protective items have on the sensory-motor performance of the individual soldier when the items are worn under conditions that minimize the contribution of such stress-related factors as extreme temperatures, elevated activity levels, and extended task durations. The research involved testing of speech intelligibility, the visual field, body mobility, and psychomotor coordination as they are affected by the material and the design configurations of the Army's standard chemical protective items. In the work involving assessment of body mobility and psychomotor coordination capabilities, the CP items were tested individually, as well as in various combinations, in order to isolate the effects of each item and to determine the extent to which the items may interact to impact performance.

SUBJECTS

The participants in this study were 12 Army men recruited from the Enlisted Volunteer Platoon at the US Army Natick Research, Development and Engineering Center. Each man volunteered after being given an explanation of the nature and the purpose of each phase of the study. The subjects ranged in age from 20 through 28 years and their mean age was 24 years.

All 12 men participated in the speech intelligibility and the visual field phases of this study. One of the men sustained an injury, outside of the context of the study, that prohibited him from taking part in the body mobility and the psychomotor testing, so only 11 of the men participated in this portion of the study.

Measurements of selected body dimensions were taken on the subjects. Descriptive statistics for the measures are presented in Table 1 and information regarding the measuring techniques employed is presented in Appendix A. Head and face dimensions were measured on the one man who participated only in the speech intelligibility and the visual field testing, but the remaining dimensions listed in Table 1 were not measured on this subject. All dimensions were measured on the 11 men who participated in the entire study. Therefore, the data for the head and the face dimensions are based on an N of 12 and the data for the other dimensions are based on an N of 11.

TABLE 1. Selected Body Dimensions of the Subjects ($11 \leq N \leq 12$)

Dimension	Mean	sd	Range	Min	Max
Stature	177.1	9.4	26.4	166.2	192.6
Shoulder Length	17.7	1.2	3.9	15.5	19.4
Sleeve Inseam Length	47.9	3.7	12.1	42.1	54.2
Waist Front Length	38.9	2.5	8.5	34.8	43.3
Waist Back Length	46.3	2.6	7.6	43.9	51.5
Interscye	42.6	3.2	10.9	38.8	49.7
Interscye, Maximum	54.7	2.7	7.8	51.4	59.2
Arm Scye Circumference	44.7	2.2	7.9	41.0	48.9
Shoulder Circumference	120.5	6.1	18.2	111.9	130.1
Chest Circumference	101.3	6.9	19.2	93.5	112.7
Waist Circumference	85.2	8.5	28.9	74.7	103.6

TABLE 1. Selected Body Dimensions of the Subjects ($11 \leq N \leq 12$) (cont'd)

Dimension	Mean	sd	Range	Min	Max
Hip Circumference	99.6	4.9	15.3	92.8	108.1
Upper Thigh Circumference	58.9	4.3	13.2	52.3	65.5
Calf Circumference	37.7	2.2	7.0	34.3	41.3
Ankle Circumference	23.0	1.2	3.8	20.7	24.5
Acromion Height	145.0	8.1	23.5	135.3	158.8
Waist Height	108.3	6.3	21.6	97.5	119.1
Crotch Height	82.3	5.9	21.8	72.1	93.9
Kneecap Height	51.9	3.5	10.5	47.5	58.0
Head Circumference[a]	56.5	1.5	5.6	53.3	58.9
Face Length[a]	12.1	0.9	2.7	10.7	13.4
Face Breadth[a]	13.8	0.6	1.8	13.1	14.9
Interpupillary Breadth[a]	5.8	0.4	1.5	5.1	6.6
Hand Length	19.0	1.3	4.0	17.2	21.2
Palm Length	11.0	0.8	2.6	9.8	12.4
Thumb Crotch Height	5.0	0.3	0.9	4.6	5.5
Hand Circumference	22.0	0.9	3.2	20.5	23.7
Wrist Circumference	17.6	0.7	2.6	16.2	18.8
Weight	81.7	11.6	33.9	67.1	101.0

NOTE: All measurements are in centimeters with the exception of weight, which is in kilograms.

[a]On these dimensions, $N=12$; on all other dimensions, $N=11$.

CLOTHING ITEMS

The chemical protective clothing used in this study included overgarments, field masks, mask hoods, overboots, and gloves with liners. Photographs of these items are presented in Appendix B. Table 2 contains a listing of the nomenclature, military specification, and stock numbers for each CP item.[11-16] Other clothing that was also worn at times during testing consisted of T-shirts, gym shorts, standard-issue, leather combat boots, and standard-issue, temperate Battle Dress Uniform (BDU) coats and trousers.

TABLE 2. Chemical Protective Items Used in Study

CP Item	Nomenclature	Specification	Stock No.
Olive-Green Overgarment	Suit, Chemical Protective (Chemical Protective Overgarment)	MIL-S-43926B, 1979	8415-01-070-1880 (XXX-Sm); 8415-01-070-1879 (XX-Sm); 8415-00-407-1060 (X-Sm); 8415-00-177-5007 (Sm); 8415-00-177-5008 (Med); 8415-00-407-1062 (Lge); 8415-00-407-1063 (X-Lge); 8415-00-407-1064 (XX-Lge)
Camouflage Overgarment	Suit, Chemical Protective (Battle Dress Overgarment)	MIL-S-43926C, 1981	8415-01-137-1700 (XXX-Sm) through 8415-01-137-1707 (XX-Lge)
Mask	Masks, Chemical-Biological, Field, M17A1	MIL-M-51282B(EA) 1976	4240-00-926-4199 (Sm) through 4240-00-926-4201 (Lge)
Hood	Hood, Chemical-Biological Mask: M6A2	MIL-H-51291A(EA) 1977	4240-00-999-0420
Overboots	Footwear Cover, Chemical Protective (Overboots)	MIL-F-43987A, 1981	8430-01-118-8172 (Sm); 8430-01-021-5978 (Lge)
Gloves	Glove Set, Chemical Protective	MIL-G-43976A, 1980	8415-00-268-8354 (X-Sm); 8415-01-033-3513(Sm) through 8415-01-033-3516 (X-Lge)

The BDU is made of a 50% nylon/50% cotton twill fabric weighing 237 g/m^2 (7.0 oz/yd^2). The coats are available in sizes ranging from X-Small through X-Large with up to six lengths in a size. The trousers are available in sizes ranging from X-Small through X-Large with up to five lengths in a size. Some finished measurements for the uniform, as presented in the specifications,[17,18] are listed in Table 3. An individual's predicted BDU coat size is based upon

TABLE 3. Finished Measurements (in cm) of the Battle Dress Uniform

Measurement	Size	XX-Short	X-Short	Length Short	Regular	Long	X-Long
				Coat			
Half Chest[a]							
	X-Small	-	51.4	51.4	51.4	-	-
	Small	56.5	56.5	56.5	56.5	56.5	56.5
	Medium	61.6	61.6	61.6	61.6	61.6	61.6
	Large	-	66.7	66.7	66.7	66.7	66.7
	X-Large	-	-	-	71.8	71.8	-
Back Length[b]							
	X-Small	-	68.9	71.4	75.2	-	-
	Small	67.6	70.2	72.7	76.5	80.0	83.5
	Medium	68.9	71.4	74.0	77.8	81.3	84.8
	Large	-	72.7	75.2	79.0	82.6	86.0
	X-Large	-	-	-	80.3	83.8	-
Sleeve Length[c]							
	X-Small	-	56.5	59.0	61.6	-	-
	Small	55.2	57.8	60.3	62.9	65.4	67.9
	Medium	56.5	59.0	61.6	64.1	66.7	69.2
	Large	-	60.3	62.9	65.4	67.9	70.5
	X-Large	-	-	-	66.7	69.2	-
				Trousers			
Half Waist[d]							
	X-Small	-	34.9	34.9	34.9	34.9	-
	Small	-	40.0	40.0	40.0	40.0	40.0
	Medium	-	45.1	45.1	45.1	45.1	45.1
	Large	-	-	50.2	50.2	50.2	50.2
	X-Large	-	-	55.2	55.2	55.2	-
Inseam[e]							
	X-Small		73.0	78.1	83.2	88.3	-
	Small	-	73.0	78.1	83.2	88.3	93.3
	Medium	-	73.0	78.1	83.2	88.3	93.3
	Large	-	-	78.1	83.2	88.3	93.3
	X-Large	-	-	78.1	83.2	88.3	-
Outseam[f]							
	X-Small	-	95.9	102.2	108.6	114.9	-
	Small	-	97.2	103.5	109.8	116.2	122.6
	Medium	-	98.4	104.8	111.1	117.5	123.8
	Large	-	-	106.0	112.4	118.7	125.1
	X-Large	-	-	107.3	113.7	120.0	-

[a]Taken at the level of the base of the armholes from folded edge to folded edge with the coat buttoned and lying flat. Tolerance: ± 1.9 cm.

chest circumference and stature, and predicted trouser size is based upon waist circumference and crotch height. The coat and the trouser sizes predicted to be worn as a function of these body dimensions are presented in the specifications[17,18] and in Table 4. Whenever the BDU was used in this study, the coat sleeves were rolled to the upper arms and the bottom of the coat was worn outside the trousers. The bottoms of the trouser legs were tied at the ankles, over the tops of the boots.

Due to a limited stock of items on hand, two types of overgarments were used in this study, both of which are standard-issue items in the Army's inventory. The overgarments are of identical design, but differ in the materials used in their fabrication. One type of overgarment, designated as the chemical protective overgarment, has an outer shell that is olive-green (Table 2). The other type, designated as the Battle Dress overgarment, has an outer shell that is a four-color, woodland camouflage pattern (Table 2). The differences between the overgarments are slight and the overgarments were judged to be equivalent for purposes of this study. Both types are pictured in Appendix Figure B-1. The olive-green overgarment was worn by two subjects and the camouflage overgarment was worn by nine subjects.

Both overgarments are two-piece suits consisting of a coat and trousers. The outer shell fabrics of the overgarments are 50% nylon/50% cotton twill. The shell fabric of both versions is water-repellent treated. The weight of the shell fabric is 186 g/m^2 (5.5 oz/yd^2) in the olive-green overgarment and 237 g/m^2 (7.0 oz/yd^2) in the camouflage overgarment. Both overgarments have a liner permanently attached to the shell fabric that is a charcoal-impregnated, 2.29-mm (90-mil) polyurethane foam and nylon tricot laminate. The liner of the camouflage overgarment is additionally composed of flame-resistant phoschek and polyethyene oxide.

The hip-length coat of the overgarments has a short, stand-up collar, full length sleeves, and a front opening with a slide fastener over which there is a protective flap secured with three snap fasteners. Each coat also has an elastic drawcord in the bottom hem, elastic braids in the sleeve hems, three

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[b]Taken along the center of the back from the undercollar seam to the bottom edge of the coat. Tolerance: ± 1.9 cm.

[c]Taken along the top of the sleeve from the setting seam to the end of the sleeve at the cuff with the sleeve folded along the underarm seam and the garment lying flat. Tolerance: ± 1.3 cm.

[d]Taken along the center of the waistband from folded edge to folded edge with the trousers buttoned and lying flat. Tolerance: ± 1.3 cm.

[e]Taken from the center of the crotch seam to the bottom edge of the trouser leg. Tolerance: ± 1.3 cm.

[f]Taken from the top of the waistband to the bottom edge of the trouser leg. Tolerance: ± 1.3 cm.

TABLE 4. Size Prediction Chart (in cm) for the Battle Dress Uniform

Body Dimension	Size	XX-Short	X-Short	Short	Regular	Long	X-Long
				Length			
				Coat			
Chest Circumference							
	X-Small	–	<83.8	<83.8	<83.8	–	–
	Small	83.8-94.0	83.8-94.0	83.8-94.0	83.8-94.0	83.8-94.0	83.8-94.0
	Medium	94.0-104.1	94.0-104.1	94.0-104.1	94.0-104.1	94.0-104.1	94.0-104.1
	Large	–	104.1-114.3	104.1-114.3	104.1-114.3	104.1-114.3	104.1-114.3
	X-Large	–	–	–	>114.3	>114.3	–
Stature							
	X-Small	–	149.9-160.0	160.0-170.2	170.2-180.3	–	–
	Small	<149.9	149.9-160.0	160.0-170.2	170.2-180.3	180.3-190.5	>190.5
	Medium	<149.9	149.9-160.0	160.0-170.2	170.2-180.3	180.3-190.5	>190.5
	Large	–	149.9-160.0	160.0-170.2	170.2-180.3	180.3-190.5	>190.5
	X-Large	–	–	–	170.2-180.3	180.3-190.5	–
				Trousers			
Waist Circumference							
	X-Small	–	<68.6	<68.6	<68.6	<68.6	–
	Small	–	68.6-78.9	68.6-78.9	68.6-78.8	68.6-78.7	68.6-78.7
	Medium	–	78.7-88.9	78.7-88.9	78.7-88.9	78.7-88.9	78.7-88.9
	Large	–	–	88.9-99.1	88.9-99.1	88.9-99.1	88.9-99.1
	X-Large	–	–	>99.1	>99.1	>99.1	–
Inseam							
	X-Small	–	<67.3	67.3-74.9	74.9-82.5	82.5-90.2	–
	Small	–	<67.3	67.3-74.9	74.9-82.5	82.5-90.2	>90.2
	Medium	–	<67.3	67.3-74.9	74.9-82.5	82.5-90.2	>90.2
	Large	–	–	67.3-74.9	74.9-82.5	82.5-90.2	>90.2
	X-Large	–	–	67.3-74.9	74.9-82.5	82.5-90.2	–

snap fastener pieces on the back of the coat at the level of the waist, and chest pockets that are lined with butyl rubber.

The trousers have a fly front with a slide fastener closure. There is a protective flap over the slide fastener and another flap under it. At the waist, there are adjustment tabs and suspender and belt loops. To aid in donning, the trousers have an opening with a slide fastener on the lateral surface of each lower leg. There is a protective flap over each slide fastener that is secured with hook-and-pile tape. There is also a drawcord in the bottom hem of each leg. A cargo pocket, lined with butyl rubber, is located on the front of each trouser leg at the level of the thigh and there are three snap fastener pieces on the back of the trousers at the level of the waist that mate with those on the coat. These are to serve to keep the lower portion of the coat from riding up over the top of the trousers.

Each type of overgarment is produced in eight sizes. Unlike the BDU, which has a number of lengths in each size category, the overgarments are available in only one length per size, and an individual's predicted size is based solely upon waist circumference. Some finished measurements for the overgarments, as presented in the specifications,[11,12] are listed in Table 5. The size predicted to be worn as a function of both an individual's waist circumference and the clothing to be worn underneath the overgarment is also included in the specifications and in Table 6.

In outfitting the subjects in this study, each man first tried an overgarment in his predicted size and then other sizes, as required, until a size was found that was not excessively tight or overly loose. Three overgarment sizes were required to outfit the subjects. The sizes used and the mean body dimensions of the men in each size category are presented in Table 7. The two men in the size X-Small wore the olive-green version of the overgarment and the remaining men wore the camouflage version. None of the overgarments used in this study had been used previously. Each subject was issued one, appropriately-sized overgarment which he wore throughout testing. The garments were not laundered over the course of the study, but they were hung in a dry place to air after each test session.

As the name implies, the overgarment coat and trousers were designed to be worn as outer garments over underwear alone or over underwear and other torso clothing, such as the BDU coat and trousers. During initial try-on and throughout the course of the study, the overgarment was worn only over a T-shirt and gym shorts. Whenever the test protocol required that it be used, the overgarment was worn in a closed configuration. That is, slide fasteners were completely closed, snaps and hook-and-pile tapes secured, and drawcords tightened and tied. The trousers were tightened at the waist using the adjustment tabs; neither a belt nor suspenders were worn.

The chemical protective mask used in this study was the standard-issue respirator which is referred to as the M17A1 (Table 2). The mask is pictured in Appendix Figure B-2 along with its protective hood, the M6A2. The mask consists of a silicon face piece and a head harness consisting of six straps with buckle adjustments. A replaceable filter element is embedded in each of the two cheek pouches. The face piece also has two, rigid, eye lenses of clear polycarbonate.

TABLE 5. Finished Measurements (in cm) of the CP Overgarment

Measurement	Size: XXX-Sm	XX-Sm	X-Sm	Sm	Med	Lge	X-Lge	XX-Lge
Coat								
Half Chest[a]	43.2	48.3	53.3	58.4	63.5	68.6	73.7	78.7
Back Length[b]	71.1	72.4	73.7	74.9	76.2	77.5	78.7	80.0
Trousers								
Half Waist[c]	33.0	38.1	43.2	48.3	53.3	58.4	63.5	68.6
Inseam[d]	80.0-81.3	80.0-81.3	80.0-81.3	80.0-81.3	80.0-81.3	80.0-81.3	80.0-81.3	80.0-81.3

[a]Taken at the level of the base of the armholes from folded edge to folded edge with the coat closed and lying flat. Tolerance: ± 1.9 cm.

[b]Taken along the center of the back from the collar joining seam to the bottom edge of the coat. Tolerance: ± 1.9 cm.

[c]Taken across the waist from folded edge to folded edge with the waist secured, the fly closed, and the trousers lying flat. Tolerance: ± 1.9 cm.

[d]Taken from the crotch seam to the bottom edge of the trouser leg.

TABLE 6. Size Prediction Chart (in cm) for the CP Overgarment

Underlying Clothing	Waist Circumference (cm) <58.4	58.5-68.6	68.7-78.7	78.8-88.9	89.0-99.1	99.2-109.2	>109.3
Underwear	XXX-Sm	XX-Sm	X-Sm	X-Sm	Sm	Med	Lge
Above + Hot Weather/ BDU coat and trousers	XXX-Sm	XX-Sm	X-Sm	Sm	Med	Lge	X-Lge
Above + Field coat and trousers	XX-Sm	X-Sm	Sm	Med	Lge	X-Lge	XX-Lge
Above + Arctic parka and trousers	X-Sm	Sm	Med	Lge	X-Lge	XX-Lge	XX-Lge

TABLE 7. Mean Dimensions of Subjects for Each Overgarment Size

Dimension	X-Small (n=2)	Small (n=4)	Medium (n=5)
		Size	
Stature	167.9	172.3	184.8
Shoulder Length	16.9	17.1	18.5
Sleeve Inseam Length	44.9	46.3	50.5
Waist Front Length	38.1	36.7	40.9
Waist Back Length	44.3	45.1	48.0
Interscye	41.2	40.5	44.8
Interscye, Maximum	52.3	53.0	57.0
Arm Scye Circumference	43.1	44.3	45.7
Shoulder Circumference	116.9	116.2	125.3
Chest Circumference	96.9	96.5	106.8
Waist Circumference	76.4	82.8	90.6
Hip Circumference	92.9	97.7	103.9
Upper Thigh Circumference	52.8	57.7	62.4
Calf Circumference	34.7	37.1	39.4
Ankle Circumference	21.6	22.6	23.8
Acromion Height	137.3	140.2	151.8
Waist Height	103.1	104.7	113.2
Crotch Height	78.0	79.5	86.2
Kneecap Height	48.9	49.7	54.9
Weight	67.5	75.2	92.6

NOTE: All measurements are in centimeters with the exception of weight, which is in kilograms.

A rubber nose cup and a voicemitter/outlet valve assembly cover most of the wearer's nose and mouth. There is also an inlet valve on each lateral surface of the mask which lies above the wearer's cheek. In this study, standard eye lens outserts were worn over the metal eyerings which secure the lenses in the face piece. The outserts are to protect the lenses from scratching.

The hood worn with the chemical protective mask is made of nylon cloth coated with butyl rubber. The hood covers the head and neck and lies on the shoulders, upper back, and chest (Appendix Figure B-2). The hood fits around the mask's metal eyerings, inlet valves, and voicemitter/outlet valve assembly. There is a slide fastener closure at the front of the hood and two straps attached at the back. Each strap is to be brought under the arm and secured to the front of the hood with hook-and-pile fastener tabs. The purpose of the straps is to keep the hood in place over the shoulders and upper regions of the chest and back. The hood also has a cord attached to its exterior surface at the neck. This cord is secured with a slider positioned in the front of the hood.

The protective mask is available in three sizes, Small, Medium, and Large. The hood is not sized, rather, it is dimensioned to fit all sizes of the mask. In outfitting the study participants in the mask, each man first tried a size Small. If the subject experienced extreme pressure from the mask or a proper seal was not obtained, then a size Medium was tried. Six of the subjects were properly accommodated in a size Small and six in a size Medium mask. Selected mean head and face dimensions of the men in each size category are presented in Table 8. Each subject was issued one mask and one hood which only he wore throughout the study. The hood was not compatible with the apparatus used for the visual field testing. Except during that portion of the study, the hood was always worn with the mask. Whenever these items were worn by the subjects, the slide fastener and straps on the hood were secured and the neck cord was drawn up to the wearer's neck.

TABLE 8. Mean Dimensions (in cm) of Subjects for Each Mask Size

	Size	
Dimension	Small (n=6)	Medium (n=6)
Head Circumference	55.9	58.5
Face Length	11.4	12.7
Face Breadth	13.5	14.0
Interpupillary Breadth	5.8	5.9

The chemical protective overboots that the subjects in the study wore have a loose-fitting upper, approximately 38.1 cm (15 in.) high, which is made of unsupported butyl rubber (Appendix Figure B-3). The upper is vulcanized to a butyl rubber sole that has a tread pattern of oval rubber cleats. There are five holes around the periphery of the sole. To secure the overboot on the foot, a long lace is passed through the holes, crossed over itself, and knotted following a pattern prescribed in instructions provided with the overboot.

The overboots are designed to be worn over standard-issue combat boots. They are available in two sizes -- one to accommodate combat boots in sizes of 3 through 7½ and the other to accommodate combat boots in sizes of 8 and up. Previously unworn overboots were distributed to the study participants on this basis with two subjects using the smaller size and the other nine using the larger. Whenever the test protocol required that the overboots and the overgarment be worn at the same time, the overboot uppers were tucked inside the trouser legs of the overgarment.

The standard-issue, chemical protective gloves used in the study are pictured in Appendix Figure B-4. The gloves, which have a thickness of 0.64 mm (25 mil), are made of butyl rubber and have a smooth surface inside and outside. The glove has five fingers and is in the shape of a relaxed, rather than a rigidly extended, hand. It is designed to be close-fitting, but not "skin-tight", and is manufactured by a process that requires the dipping of porcelain hand forms into a rubber solution. The gauntlet of the glove extends well beyond the wrist. When flat and unstretched, the gloves measure between 35.6 cm and 36.8 cm (14.0 in. and 14.5 in.) from the tip of the middle finger to the edge of the rolled cuff. The butyl gloves are issued to Army personnel along with a pair of lightweight, stretchable, knitted cotton glove liners. The cotton liners conform closely to the shape of the hand and have an unfinished cuff which lies at the wrist. These liners are worn under the butyl gloves to aid in the absorption of moisture which accumulates within the impermeable rubber glove.

The protective gloves are produced in five sizes. To select sizes for the study participants, each man first tried a size Medium and then other sizes as required until a size was identified in which the amount of excess material at the fingertips was minimized and the fit across the knuckles and the palm of the hand was not binding. Three sizes were required to accommodate the subjects. The sizes used and selected mean hand dimensions of the men in each size category are presented in Table 9. Each man was issued one pair of gloves and one pair of liners, which had not been worn previously, for use during the study. Liners were worn whenever the butyl gloves were used. When the gloves and the overgarment were worn at the same time, the gauntlets of the gloves were tucked inside the sleeves of the overgarment.

TABLE 9. Mean Dimensions (in cm) of Subjects for Each Glove Size

	Size		
Dimension	Small (n=3)	Medium (n=7)	Large (n=1)
Hand Length	18.0	19.5	19.2
Palm Length	10.4	11.2	11.1
Thumb Crotch Height	5.1	5.0	4.9
Hand Circumference	21.0	22.2	23.7
Wrist Circumference	16.8	17.7	18.8

SPEECH INTELLIGIBILITY TESTING

Purpose

The purpose of this phase of the study was to assess the effects of the chemical protective mask and hood on voice communication. The capacity to understand speech while wearing the mask and hood (hearing) and the capacity to be understood while wearing the mask and hood (speech communication) were evaluated in this investigation. Both hearing and speech communication were assessed through the use of the Modified Rhyme Test.[19] This is an objective test designed to evaluate the ability to correctly identify spoken words.

The Modified Rhyme Test consists of six equivalent lists, each composed of 50 monosyllabic words which are presented orally. The words are generally of the form consonant-vowel-consonant. For each stimulus word, the listener has available on a printed answer sheet a closed set of six alternatives from which the stimulus word must be selected. A set of six alternatives is characterized by one vowel that is the nucleus of each word in it. All words in a given set are initiated by the same consonantal phoneme or phoneme cluster and terminated by six different phonemic elements, or vice versa (e.g., did, dim, dig or kick, sick, tick). The Modified Rhyme Test has been found to be efficient and useful because it entails only minimal listener training and requires perception of consonantal sounds.[20] These sounds are difficult to transmit successfully and are thus more important than vowels to intelligibility.

Method

Subjects. All 12 of the men who initially volunteered for this study took part in the testing of speech intelligibility. No man reported having a history of hearing problems requiring medical attention.

Clothing conditions. The Modified Rhyme Test was administered under four experimental conditions. In one, the individual speaking the words (talker) and the individual listening to the words (listener) were bareheaded. In a second condition, both individuals wore the mask and hood. In a third condition, the talker was bareheaded and the listener wore a mask and hood. In a fourth condition, the talker wore a mask and hood and the listener was bareheaded. The sequence of presentation of the four conditions was counterbalanced across subjects. Under all conditions, the subjects wore their regular duty uniforms, which consisted of the Battle Dress Uniform coat and trousers and combat boots.

Apparatus and procedure. A male experimenter served as the talker in this test. He practiced presentation of the word lists extensively with the aim of attaining a normal conversational level. A Gen Rad 1995 Integrating Real-Time (Spectrum) Analyzer was used to check the level, as well as the uniformity, of presentation. The experimenter, while bareheaded, then recorded on cassette tape the six lists of words that comprise the Modified Rhyme Test for use during the subjects' practice on the test. Four of the six lists were randomly selected for presentation during the experiment proper. The words on each of the four selected lists were reordered randomly before the lists were recorded on tape. The experimenter recorded two of the lists while bareheaded and two

while wearing the mask and hood. All word lists and an example of a listener's answer sheet are reproduced in Appendix C.

The recording of the lists took place in a sound attenuation chamber. White noise was also recorded in this chamber to be played as a background noise during presentation of the lists. The white noise was produced by a General Radio Random-Noise Generator, Model 1382. An Electrovoice microphone, designed for voice reproduction, and a Fostex Tape Deck, Model 250 AV, were used for recording the lists and the white noise. All lists were recorded using identical settings on the audio equipment.

The same cassette deck and a matching Fostex Bookshelf speaker of acoustic suspension design were used for simultaneous playback of voice and noise. Presentation of the recorded lists was carried out in the sound attenuation chamber with the speaker positioned approximately 114 cm (45 in.) above the floor and approximately 1.65 m (6.5 ft) in front of the seated listener. Pilot testing was conducted to determine the volume level for playback of the tapes. The level selected and used throughout the remainder of this work was such that bareheaded pilot subjects correctly identified between 44 and 49 out of 50 words on lists recorded while the talker was bareheaded.

The subjects participated in two sessions that were conducted on consecutive days. Eight subjects were run in pairs, one subject was run alone, and the remaining three were run as a group. During the first, or practice, session, they were tested on the six word lists while bareheaded. Thus, each word included in the Modified Rhyme Test had been presented to the subjects once before they began the second session, the actual testing session. During the test session, the presentation of the two lists recorded by the bareheaded talker was arranged so that half of the subjects were given one list while they were bareheaded and half were given the list while they were wearing the mask and hood. This strategy was also used in the presentation of the two lists recorded by the talker while he was wearing the mask and hood.

The same basic procedure was employed at both sessions. The subject was seated in the sound attenuation chamber, in which the ambient temperature was 21.1°C (70°F), and given a set of answer sheets. The instructions, which are included in Appendix C, were read by the experimenter. The presentation of a prerecorded list was then initiated. There was a 5-second interval between word presentations during which time the subject was to select the stimulus word from the set of six alternatives. A word list was completed in about 8 minutes and was followed by an 8-minute rest period. A subject's score was the percentage of words identified correctly of the 50 on a list.

The percentage scores were subjected to a two-way, repeated measures analysis of variance of the form: Subjects (1-12) x Talker Headwear (bare head, mask and hood) x Listener Headwear (bare head, mask and hood). The analysis was performed on a Univac 1106 computer using BMDP-81 program P8V.[21]

Results and Discussion

A summary of the analysis of variance performed on the Modified Rhyme Test data is presented in Table 10. It can be seen that the Talker Headwear x Listener Headwear interaction was not significant ($p > .05$) and that both main effects were. Failure to obtain a significant interaction indicates that the relationship between the scores for the two talker headwear conditions did not vary with listener headwear condition, and vice versa. The mean for each talker headwear condition, calculated over subjects and listener headwear condition, is presented in Figure 1a. It can be seen that the significant main effect of talker headwear was attributable to a lower percentage of correct responses when the talker was wearing the mask and hood than when he was bareheaded. Also included in Figure 1a is the mean for each listener headwear condition, calculated over subjects and talker headwear condition. Again it can be seen that the significant main effect of listener headwear was attributable to a lower percentage of correct responses when the listener was wearing the mask and hood than when he was bareheaded. Thus, relative to the bare head, use of the mask and hood significantly degraded the talker's ability to communicate and the listener's ability to understand spoken words.

TABLE 10. Analysis of Variance of Modified Rhyme Test Data

Source of Variance	df	MS	F
Subjects (S)	11	61.30	-
Talker Headwear (T)	1	5504.08	164.12***
Listener Headwear (L)	1	420.08	10.39**
S x T	11	33.54	-
S x L	11	40.45	-
T x L	1	80.08	1.68
S x T x L	11	47.72	-

**$p < .01$
***$p < .001$

Although it is not surprising that the subjects experienced difficulties understanding the talker when he was communicating through the mask's voicemitter assembly, it is somewhat surprising that the subjects' use of the mask and hood degraded their hearing to the extent that it did. Their decreased performance levels may be attributable, at least in part, to impeded acoustic transmission associated with the butyl rubber hood. It is also possible that the subjects themselves generated noise while breathing in the mask that further impaired their ability to hear because the mask's inlet valves are audible to the wearer as they open and close during respiration as is the passage of expired air through the outlet valves.

Figure 1b is a graph of the mean percentage of correct responses as a function of each combination of talker and listener headwear. These mean scores for the four experimental conditions included in this testing can be put in perspective when compared with the intelligibility criteria for voice communication systems set forth in MIL-STD-1472C.[22] A mean of 9[illegible]% of the spoken words was identified correctly when both the talker and the listener were bareheaded. According to the MIL-STD, this equates with normally acceptable intelligibility. At this level, it is expected that single digits will be understood and that about 98% of spoken sentences will be heard correctly.

A mean of 88% correct identifications was obtained on the Modified Rhyme Test when the talker was bareheaded and the listener wore the mask and hood (Figure 1b). While somewhat below the level of normally acceptable intelligibility, this mean score is well above the minimally acceptable level that MIL-STD-1472C[22] sets at a score of 75% correct identifications on the Modified Rhyme Test. At the level of minimally acceptable intelligibility, it is expected that limited standard phrases will be understood and about 90% of sentences will be heard correctly. The mean obtained when only the talker wore the mask and hood was 72% correct identifications and, when the talker and the listener both wore the headgear, a mean of 64% of the words were chosen correctly (Figure 1b). Thus, both conditions in which the talker used the mask and hood were below the minimally acceptable level for voice communication. The fact that the lowest scores on the Modified Rhyme Test were achieved when both the talker and the listener were wearing the mask and hood, a normal situation in a chemical environment, highlights the difficulties in voice communication that can be expected in a chemical warfare scenario.

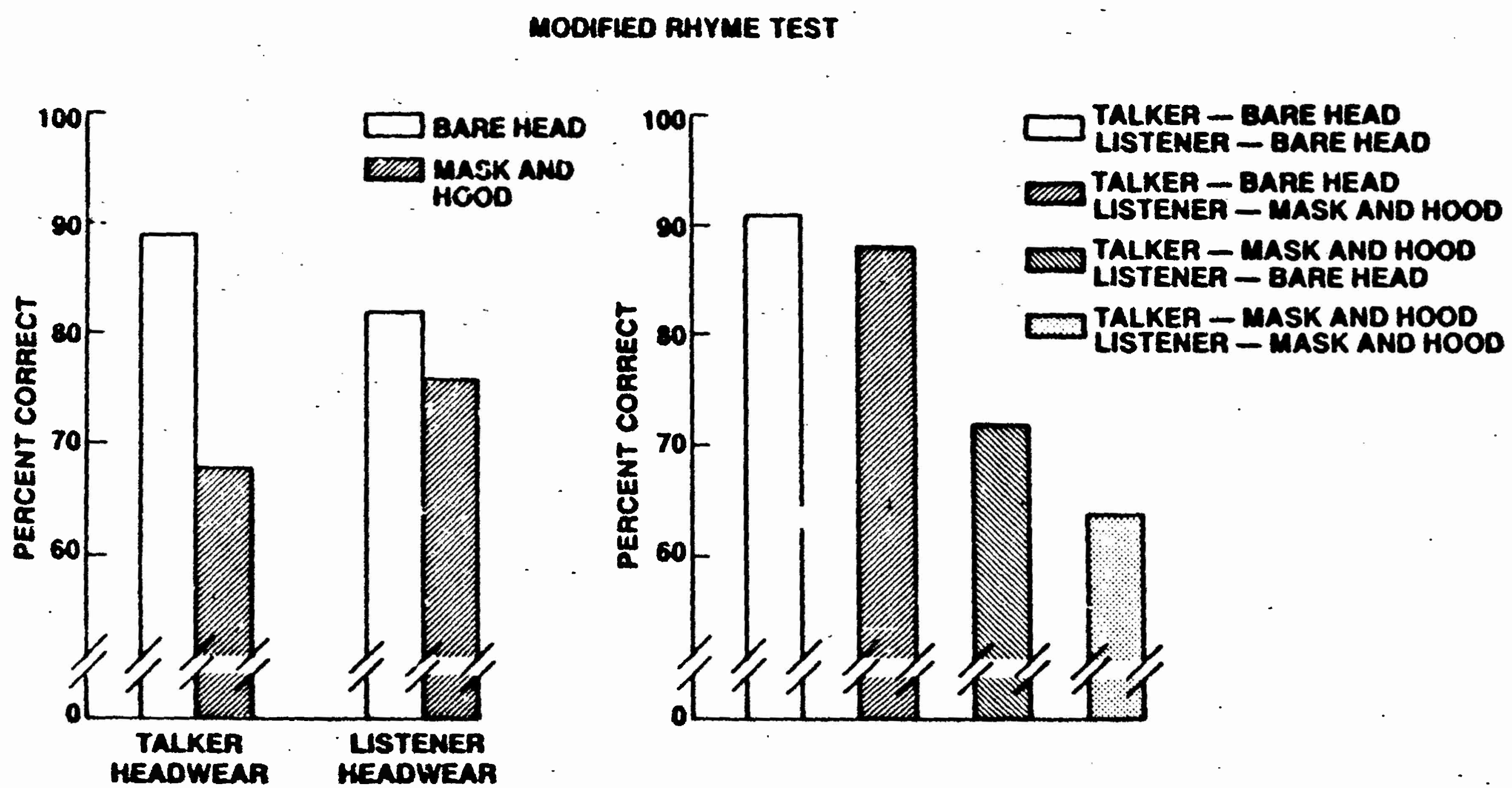

Figure 1a. Mean percentage correct on the Modified Rhyme Test as a function of headwear condition of the talker and the listener.

Figure 1b. Mean percentage correct on the Modified Rhyme Test for each experimental condition.

VISUAL FIELD TESTING

Purpose

The purpose of this testing was to determine the limits of the visual field of men wearing the mask and to compare the limits with those of the visual field when the men were bareheaded. Ten areas of the visual field were selected for testing and measurements were made monocularly for each of the areas. Both the right and the left eyes were tested.

Kobrick and Sleeper[23] investigated the effects of the chemical protective mask compared with the bare head on binocular, rather than monocular, vision using a reaction time test. When tested bareheaded, their subjects wore the Battle Dress Uniform coat and trousers. When tested in the mask, the subjects also wore the chemical protective overgarment, hood, overboots, and gloves. The visual reaction time test required that subjects keep their heads in a fixed position and monitor stimulus lights distributed about a hemisphere in front of which the subjects were positioned. A switch was to be depressed whenever the onset of a signal light was detected. Kobrick and Sleeper found that mean reaction times increased with greater peripheralization of the stimulus lights, regardless of whether the subjects were bareheaded or masked. However, reaction times were substantially longer when the chemical protective system was being worn. In addition, under both the bare-head and the mask conditions, reaction times associated with stimuli located in the superior and the inferior areas of the visual field were longer than those associated with stimuli along the horizontal axis of view. Again, reaction times were impaired substantially by use of the mask regardless of the axis of view.

Kobrick and Sleeper[23] concluded that the mask imposes a serious impairment on functional vision. However, their study did not include determination of the actual limits of the visual field of a masked individual. Such data were acquired in the present investigation.

Method

Subjects. All 12 of the men who initially volunteered for the study took part in the visual field testing. No man reported having visual problems requiring the use of corrective lenses.

Clothing conditions. Measurements of the visual field were made while the subject was bareheaded and while the mask was being worn. The hood was not used because it was not compatible with the test apparatus. Throughout testing, the subjects wore their regular duty uniforms which consisted of the Battle Dress Uniform coat and trousers and combat boots.

Apparatus and procedure. A Topcon Projection Perimeter (Goldman type), Model SBP-20, was used to assess the visual field under darkened room illumination. A photograph of the perimeter is presented in Figure 2. The target, a white spot of light, was projected onto a white, hemispherical surface. The radius of the hemisphere was 30 cm (11.8 in.). The background luminance of the surface of the hemisphere was maintained at 10 cd/m^2. The

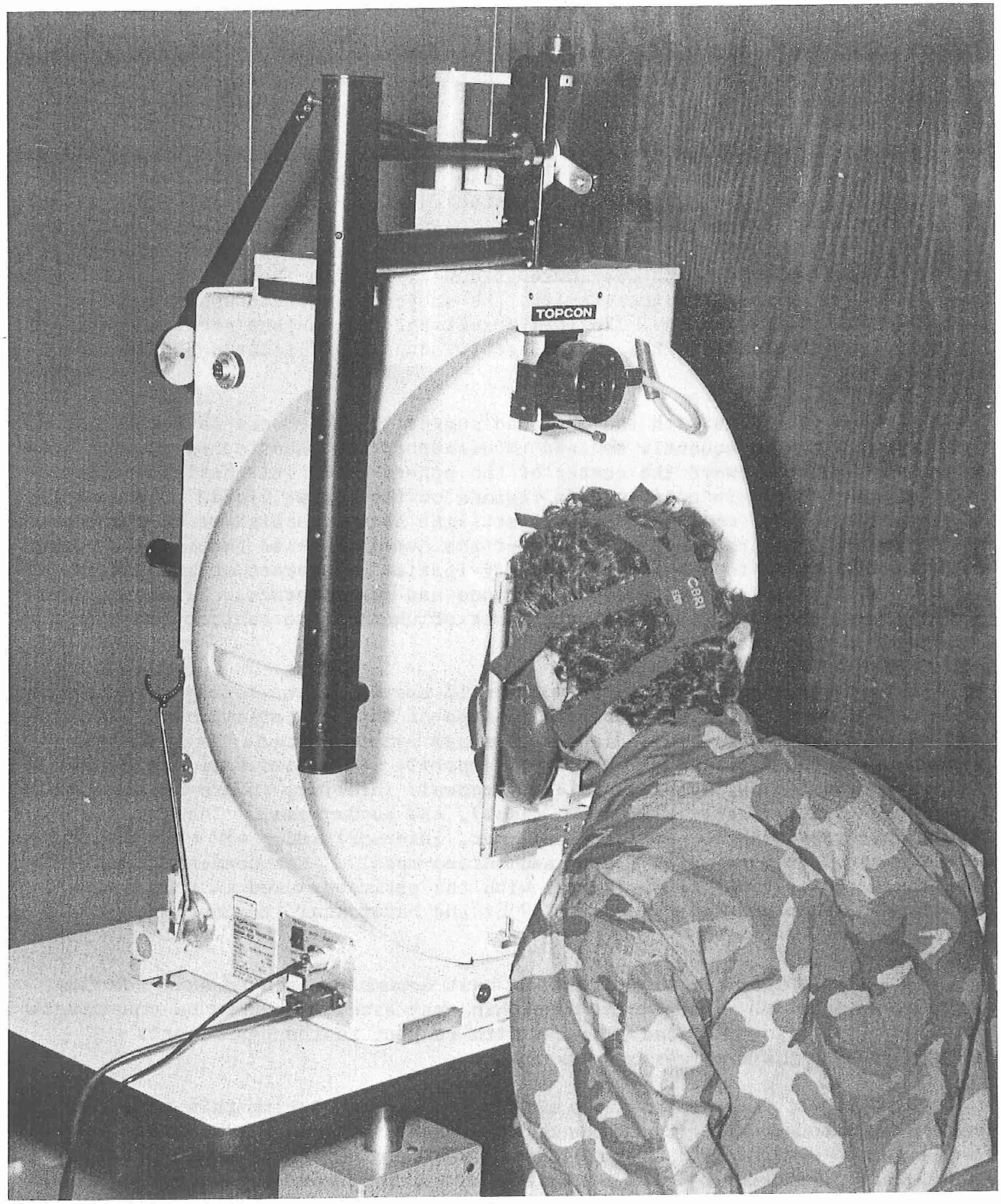

Figure 2. Visual perimetry setup.

target light spot was adjusted to a luminance of 318 cd/m^2. The diameter of the target was set at 16 mm^2 (0.02 in.^{2}) so that the target subtended a visual angle of approximately 0.9°.

The limits of the visual field were assessed using the following technique. First, the position of the head was adjusted in a head/chin rest assembly in order to place the eye that was to be tested directly in front of the fixation point located at the center of the sphere. An eye patch was placed over the other eye. Once in the appropriate position, the subject fixated the central point while the target light was moved gradually in from the periphery along the axis under test. By pressing a switch, the subject indicated when the light spot was initially detected. The switch activated a pen that recorded the limit of the visual field along this axis directly on a chart situated behind the hemisphere.

Pilot observations with the mask had suggested that, once detected, the light spot might subsequently be seen to disappear and then to reappear if it was kept in motion toward the center of the sphere after its initial detection. This seemed to occur in only certain regions of the visual field. Consequently, in the actual study, movement of a target light along an axis was terminated only when the light reached the center of the hemisphere and the subject was requested to attend to and report not only initial appearance of the target light, but also any subsequent disappearance and reappearance. This procedure was followed throughout testing, regardless of whether the subject was bareheaded or was wearing the mask.

Perimetric measurements were made for 10 areas of the visual field of each eye. For each of the 10, a measure was taken of initial detection of the target spot and, if applicable, its disappearance and reappearance. The 10 areas tested were: superior, super-temporal, temporal$_1$ (15° above temporal), temporal$_2$ (15° below temporal), infero-temporal, inferior, infero-nasal, nasal$_2$ (15° below nasal), nasal$_1$ (15° above nasal), and super-nasal. The axes represented included the vertical (superior, inferior) and $\pm$ 45° of the vertical (super- and infero-temporal, super- and infero-nasal). Measurements could not be made directly along the horizontal with the perimeter used in this study. Therefore, measurements were made $\pm$ 15° of the horizontal (temporal$_{1\&2}$, nasal$_{1\&2}$).

The manufacturer-supplied head/chin rest assembly was used only for the bare-head condition. A different head/chin rest assembly had to be constructed in order to position the head properly with respect to the perimeter's hemisphere when the mask was being worn.

Each subject participated in a one-hour session. During this time, each eye was tested separately under one of the two clothing conditions, the subject was given a 10-minute rest, and each eye was tested under the other clothing condition. The order of presentation of the clothing conditions and the order in which each eye was tested were counterbalanced across subjects. Ambient room temperature was maintained at 21.1°C (70°F).

No statistical analyses were performed on the perimetric data. Means were calculated from the data of the 12 subjects to describe the visual field for each eye under each clothing condition.

Results and Discussion

When wearing the mask, the majority of subjects did not first detect the target light in the $nasal_1$ and the $nasal_2$ regions through the lens covering the eye being tested, but rather initial detection of the target light was through the opposite lens. Ten of the 12 subjects reported this experience on at least one occasion. In each instance in which this occurred, the subject subsequently reported that the target light disappeared from the field of view and then reappeared. Reappearance of the target was detected through the lens covering the eye being tested. This occurred only in the $nasal_1$ and the $nasal_2$ regions. Since pilot subjects had also reported this experience, the test subjects had been instructed to signal not only their first detection of the target light, but also any subsequent disappearance and reappearance.

The means obtained for each region of the visual field under both the bare-head and the mask conditions are listed in Table 11. For the $nasal_1$ and the $nasal_2$ regions, the data presented on the mask condition include, first, the mean for the initial detection of the target light through the lens covering the eye under test, followed in the table by the mean for the first detection of the target light through the opposite lens, and then the mean for the disappearance of the target light. It can be seen in Table 11 that the means for the first sighting of the target through the opposite lens are very similar to the means for initial detection of the target under the bare-head condition. The means for the $nasal_1$ and the $nasal_2$ regions also indicate that, once the target light was moved in from the periphery by some 16° to 17° from the point of first detection, it disappeared and was not detected through the lens covering the eye under test until it had been displaced approximately 22° further toward the fixation point, the center of the visual field.

These findings for the $nasal_1$ and the $nasal_2$ regions indicate that for most subjects, but not all, the separation between the interior of the mask and the nasal area of the face was great enough so that the visual field in the nasal area encompassed both lenses of the mask instead of just one. The mask's opaque nose bridge, however, created a blind spot that blocked the subject's view of the target light until the target was moved closer to the center of the visual field and within the limits imposed by the lens covering the eye under test.

Because this phenomenon of twice detecting the light was not experienced by all subjects, its occurrence may be a function of differences among subjects in the fit of the mask's face piece. The possibility that it was due to the manner in which a subject positioned the mask on this particular occasion also cannot be ruled out. Each subject was tested only once, and there is, therefore, no basis for determining whether or not a subject would have experienced this phenomenon consistently over several testing sessions. However, after testing of one eye had been completed, the subjects had to doff the mask so that the eye patch could be repositioned, and it is interesting to note that seven of the 10 subjects who reported detecting the light twice in the $nasal_1$ area had this experience during testing of both the right and the left eyes as did six of the eight subjects who detected the light twice in the $nasal_2$ area.

TABLE 11. Mean Visual Field (in degrees) of Each Eye for the Bare-Head and the Mask Conditions

Region	Right Eye Bare Head	Right Eye Mask	Left Eye Bare Head	Left Eye Mask
Superior	47	30	47	31
Super-Temporal	66	57	64	58
$Temporal_1$	89	83	88	84
$Temporal_2$	90	81	90	80
Infero-Temporal	85	65	83	61
Inferior	71	32	69	25
Infero-Nasal	49	17	48	14
$Nasal_2$	57	17	55	14
Target Sighted Through Opposite Lens	-	56[a]	-	53[a]
Disappearance of Target	-	39[a]	-	37[a]
$Nasal_1$	60	19	59	16
Target Sighted Through Opposite Lens	-	56[b]	-	55[c]
Disappearance of Target	-	40[b]	-	39[c]
Super-Nasal	53	24	50	20

NOTE: Unless otherwise indicated, N=12.

[a]N=7

[b]N=8

[c]N=9

As can be seen in Table 11, the mean visual fields of the right and the left eyes are very similar under the bare-head condition. This is also the case under the mask condition. The measurements from each eye were, therefore, combined, reversing portions of the visual field of the left eye as required, to obtain one mean value for each of the 10 areas of the visual field. The data for both eyes combined were plotted in order to illustrate the differences between the visual fields for the bare-head and the mask conditions. The plots are presented in Figure 3. The only means for the $nasal_1$ and the $nasal_2$ regions under the mask condition that have been included in the figure are those associated with detection of the target light through the lens covering the eye under test because the phenomenon of twice detecting the light was not experienced by all subjects and the consistency of occurrence of this phenomenon among the subjects who did experience it cannot be established on the basis of this study.

It is obvious from Figure 3 that each of the 10 areas of the visual field measured was restricted to some extent when the mask was worn relative to the visual field when the head was bare. The means for the mask condition that most closely approximate those for the bare-head condition are in the superior, the $temporal_1$, and the $temporal_2$ regions. The greatest differences between the two conditions are in the $nasal_1$, the $nasal_2$, and the inferior regions (Figure 3). With the exception of these three regions, the shape of the visual field for the mask is not unlike the shape of a mask lens. It is possible that the nose cup in the mask's interior or that part of the voicemitter assembly on the exterior of the mask restricts the nasal and the inferior portions of the visual field beyond the limitations imposed by the lens itself.

The findings from this testing indicate that the visual field is restricted substantially when the mask is worn and, as Kobrick and Sleeper[23] proposed, lead to the conclusion that the mask imposes a serious impairment on functional vision.

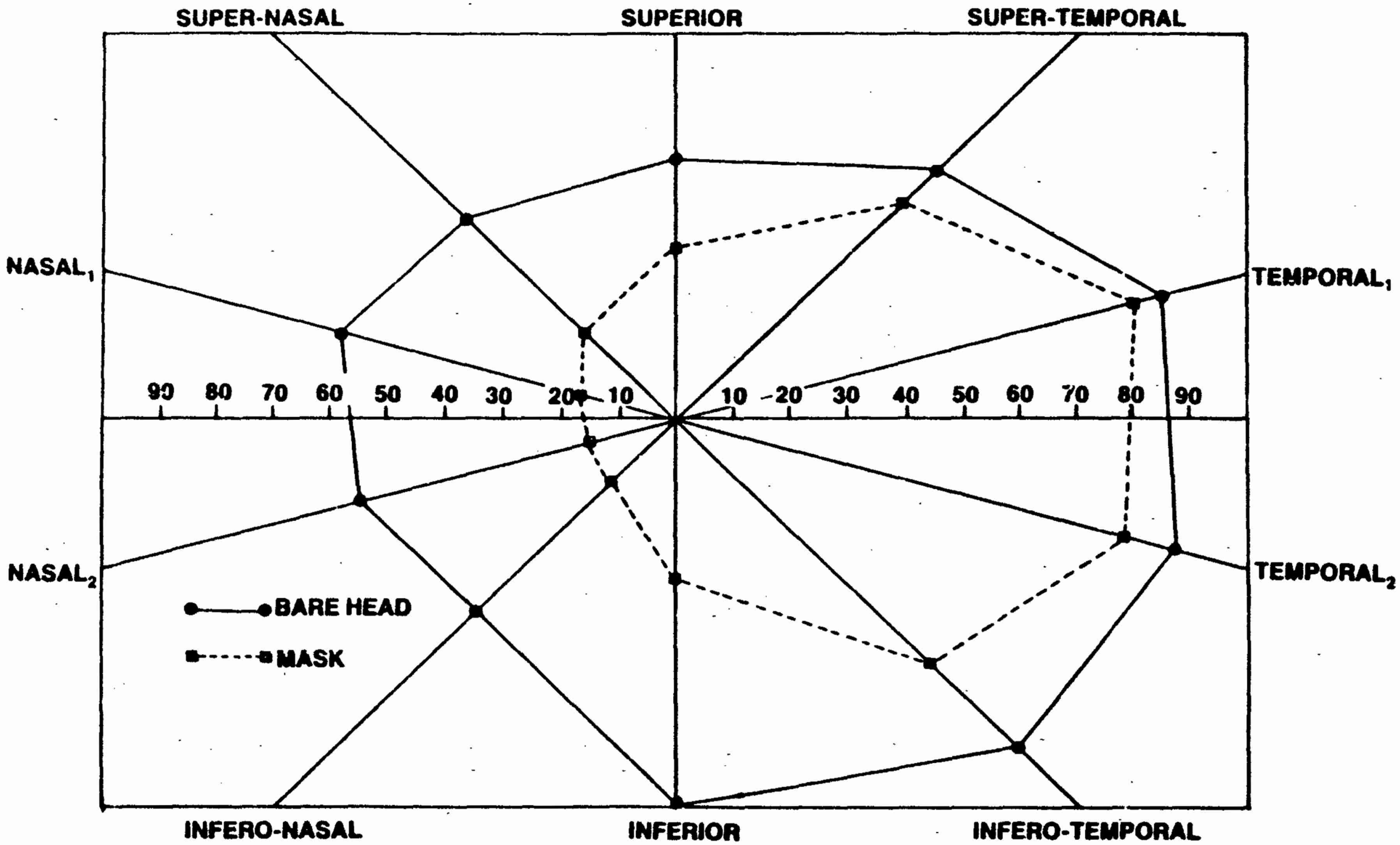

Figure 3. Mean visual field of both eyes combined for the bare-head and mask conditions.

BODY MOBILITY AND PSYCHOMOTOR COORDINATION TESTING

Purpose

The purpose of this testing was to evaluate the effects of the standard chemical protective overgarment, mask and hood, overboots, and gloves on the body mobility and the psychomotor coordination capabilities of men. The body mobility tasks have been employed in previous clothing evaluation studies and evolved principally from an investigation by Saul and Jaffe.[24] The purpose of their study was to develop and analyze quantitative techniques for measuring movement interference due to clothing and equipment. The mobility tasks were used by Saul and Jaffe to measure the limits of movement of various parts of the body, including the head and neck, the arm and shoulder, the trunk and waist, and the leg and hip. The tasks involved movement of body segments in the frontal, the sagittal, and the transverse planes of the body.[25]

The mobility tasks used in the present study were the following: (1) Standing Trunk Flexion, (2) Upper Arm Abduction, (3) Upper Arm Forward Extension, (4) Upper Arm Backward Extension, (5) Upper Leg Flexion, (6) Upper Leg Forward Extension, (7) Upper Leg Abduction, (8) Upper Leg Backward Extension, (9) Ventral-Dorsal Head Flexion, and (10) Head Rotation. Standing Trunk Flexion required bending of the upper trunk at the waist in the body's sagittal plane. Upper Arm and Upper Leg Abduction involved movement in the frontal plane, whereas Forward and Backward Upper Arm and Upper Leg Extension and Upper Leg Flexion were movements in the body's sagittal plane.

Some of these mobility tasks were used in a study conducted by Lockhart and Bensel.[26] In that study, men performed the tasks while wearing from one through five layers of cold weather clothing over winter underwear. In general, the extent of the body movements was increasingly restricted with the addition of each clothing layer. Standing Trunk Flexion appeared to be sensitive to the amount of clothing bulk in the waist area. Upper Arm Abduction, Forward Extension, and Backward Extension seemed to be affected by bulk, as well as by the ease with which the clothing layers moved relative to each other.

With the exception of Upper Leg Backward Extension, all of the mobility tasks used in the present study were included in a study conducted by Bensel, Fink, and Mellian[27] to evaluate two types of armor vests. Bensel et al. found that use of either armor vest decreased the extent of Ventral-Dorsal Head Flexion and Head Rotation compared with that achieved when only the coat and trousers of a field duty uniform were worn. Both vests had relatively rigid, stand-up collars which limited the head movements. The lengths and the rigidity of the vests also limited the extent to which the leg could be raised in the body's frontal plane as evidenced by performance on the Upper Leg Abduction task.

In addition to the 10 tasks involving body mobility included in the present study, two visual-motor coordination tasks were used, the Pursuit Rotor and the Railwalk. The former required that the subject use a stylus to track a target that moved in a circle. The stylus was grasped in the hand, and tracking was accomplished by movement of the arm and shoulder. In their study of the effects of layers of cold weather clothing on men's performance, Lockhart and Bensel[26]

found that scores on the Pursuit Rotor generally decreased as the number of clothing layers being worn increased. Similar results were obtained in a study of the effects of cold weather clothing on women's performance.[28] It appears that increasing the layers of clothing interfered with the smooth and regular arm movements needed to successfully track the target on the Pursuit Rotor test.

For the Railwalk, the other visual-motor coordination task included in the present study, the subject was to walk a narrow rail, which was slightly elevated from the floor, in heel-to-toe fashion with his hands clasped behind his back. Saul and Jaffe[24] found that the subjects progressed farther along the rail before losing their balance and touching a foot to the floor when they were wearing T-shirts and shorts than when their torsos were encumbered by two layers of arctic clothing. Bensel et al.[27] also found that the use of body armor vests in combination with load-carrying equipment had a negative impact on execution of the Railwalk.

Two other tests of coordination that involved manual dexterity were also used in the present study. The tests were the Purdue Pegboard Assembly Test, which required simultaneous movement of both hands, and the O'Connor Finger Dexterity Test, which was done with one hand. The O'Connor Test was used in a study of chemical protective handwear conducted by Bensel[29] and was found to differentiate between two types of rubber gloves that varied in thickness and basic dimensions. No handwear was worn in the study of cold weather clothing conducted by Bensel et al.[28] However, they found that women's performance on the Purdue Pegboard Assembly Test worsened as the layers of clothing were added to the torso. It appeared that the sleeves increasingly obscured the task board as the layers were added.

In addition to the quantitative measures of performance on the body mobility and psychomotor tasks, a questionnaire was employed in the present study to obtain subjective reports regarding the chemical protective clothing being worn. The subjects were asked to indicate the extent to which the clothing worn interfered with performance of each task and to rate the impact of various clothing design characteristics on performance. The questionnaire used here was similar to one devised by Lockhart and Bensel[26] for their study of cold weather clothing.

Subjects performed the body mobility and the psychomotor tasks while wearing various combinations of the standard chemical protective clothing items. They also carried out the tasks while wearing the Battle Dress Uniform (BDU) coat and trousers and while wearing a T-shirt and shorts. The clothing conditions tested were selected in order to carry out five investigations of the effects of chemical protective clothing on body mobility and psychomotor performance. The nature of each investigation is described here.

1. <u>Investigation I. Comparison of MOPP IV with the BDU</u>. One of the more common field duty uniforms worn by soldiers is the BDU coat and trousers. This is worn over undershorts and a T-shirt. The footwear generally used with the BDU is the standard leather combat boot. The highest level of protection for the individual soldier in a chemical warfare environment is achieved when all components of the chemical protective clothing system are being worn. This is

the fourth level of Mission-Oriented Protective Posture (MOPP IV).[30] Investigation I was conducted to identify the impact that the MOPP IV level of protection had on the subjects' ability to perform the body mobility and the psychomotor tasks relative to their ability when outfitted in torso attire commonly worn in the absence of a chemical threat.

2. Investigation II. Comparison of the CP overgarment with other torso clothing. This investigation also involved the BDU. The purpose was to examine whether or not there are material and design differences between the BDU coat and trousers and the coat and trousers of the chemical protective overgarment that affect body mobility and psychomotor performance. No other CP items were included. However, performance in the BDU and in the overgarment was compared with performance when the encumbrance of torso clothing was minimal, that is, when only a T-shirt and shorts were being worn.

3. Investigation III. Individual and combined effects of CP items exclusive of the CP overgarment. The overgarment is the foundation of the soldier's chemical protective system. As the threat of chemical exposure increases, the mask and hood, the overboots, and the gloves are worn with the overgarment for increased protection. In this investigation, however, the CP overgarment was not used in order to examine the effects on the body mobility and the psychomotor tasks of the other protective items when the encumbrance of clothing on the torso is minimized. The torso clothing consisted of a T-shirt and shorts. The mask and hood, the overboots, and the gloves were worn as well, both individually and in various combinations.

4. Investigation IV. Effects of wearing CP items with the CP overgarment. This investigation was similar to Investigation III except that the CP overgarment was used throughout as the basic torso clothing. The other protective items were worn with it one at a time and in various combinations. Thus, the effects on the body mobility and the psychomotor tasks of the individual components of the chemical protective clothing system and the interactions among the components could be examined.

5. Investigation V. Comparison of MOPP levels. The Army has developed guidance that gives field commanders whose troops are operating in the presence of a chemical warfare threat a range of choices as to the use of chemical protective clothing. The commander determines the items of chemical protection to be worn by the individual soldier on the basis of the threat, the work rate imposed by the mission, and the ambient temperature, humidity, and windspeed.[31] This flexible system of protection, referred to as Mission-Oriented Protective Posture (MOPP), consists of four levels that the commander may prescribe (MOPP I-IV)[31] At the first level, the protective overgarment is worn. At the next level, the overboots are also used. The mask is donned at the third level and, at the fourth level, the gloves are added. The purpose of this investigation was to examine the effects on body mobility and psychomotor performance of varying the level of protection of the soldier from MOPP I through MOPP IV.

The Method section which follows contains information regarding the subjects, the mobility and the psychomotor tasks, and the procedure that is common to all five investigations. Details specific to a particular

investigation and the findings related to each are presented separately in subsequent sections of this report.

Method

Subjects. Eleven of the 12 men who initially volunteered for this study took part in the testing of body mobility and psychomotor coordination. The twelfth man sustained an injury, outside of the context of the study, that prohibited his participation in this phase of the testing.

Tasks and questionnaire. The tasks included in this phase of the study consisted of 10 tests of gross body mobility and four tests of psychomotor coordination. With the exception of Standing Trunk Flexion, the body mobility tasks involved the use of a goniometer to measure the angular displacement of various parts of the body. The goniometer is an instrument consisting of a rotatable pendulum mounted in front of a moveable, 360° scale. Both the scale and the pendulum are mounted on a thin block that is attached to a long strap. Accurate use of the goniometer demands that the scale remain in an almost vertical plane so that the pendulum can rotate freely to the vertical. In this study, the goniometer was strapped in a vertical position to a part of the body and set to zero by turning the moveable scale until the 0° mark coincided with the pendulum. The subjects were then instructed to move their bodies in a certain fashion and, when the maximum amplitude was reached, the degrees of arc through which the body part had passed were read directly from the point on the scale with which the pendulum was then aligned.

One administration of a body mobility task consisted of four, successive trials. This was also the case for the Pursuit Rotor and the Railwalk. Because of time constraints and the fatiguing nature of the tasks, one trial was administered on the O'Connor Finger Dexterity and the Purdue Pegboard Assembly Tests. The tasks were executed in a standard manner and in the same order for all subjects. The 10 body mobility tasks are briefly described here in the order in which they were performed, as are the four tests of psychomotor coordination. Additional information regarding the battery of tasks and directions for administering each task are presented in Appendix D.

1. Standing Trunk Flexion.[32] The subject was instructed to bend at the waist and reach down toward the floor as far as possible while keeping the knees stiff. The score was the distance, in centimeters, between the tips of the middle fingers and the floor. A score of 0.0 cm was assigned if the subject touched the floor with his fingertips.

2. Upper Arm Abduction.[33] The goniometer was placed on the right arm above the elbow. The subject stood erect facing a wall, with his body touching a projecting corner of the wall, and the goniometer was set to zero. Both arms were raised sideward and upward as far as possible with the elbows being kept stiff, and the angular displacement was read, in degrees, from the goniometer.

3. Upper Arm Forward Extension.[34] The goniometer was placed on the right arm above the elbow. The subject was positioned facing a wall with his right arm and shoulder just past the edge of the wall. He stood erect with his arms

at his sides and his elbows stiff, and the goniometer was set to zero. The right arm was then raised as far forward and up as possible with the elbow being kept stiff. The angular displacement was read, in degrees, from the goniometer.

4. Upper Arm Backward Extension.[24] The goniometer was placed on the right arm above the elbow. The subject stood erect with his back against a wall, and his right shoulder and arm just past its edge. His arms were at his sides and his elbows stiff. He rotated his right arm until the palm was facing out and the thumb was pointed dorsally. The goniometer was set to zero. The right arm was then raised backward as far as possible, with the elbow being kept stiff, and the angular displacement was read, in degrees, from the goniometer.

5. Upper Leg Flexion.[24] The subject stood erect with his back against a wall and his feet together. The goniometer was placed on the right leg above the knee and set to zero. Supporting himself with the left hand on the back of a chair positioned to the left side, the subject raised his right upper leg as far as possible while letting his right knee bend freely. The maximum angular displacement was read, in degrees, from the goniometer.

6. Upper Leg Forward Extension.[26] The subject stood erect with his back against a wall and his feet together. The goniometer was placed on the right leg above the knee and set to zero. Supporting himself with the left hand on the back of a chair positioned to the left side, the subject raised his right leg forward while keeping his knee stiff, and angular displacement was read, in degrees, from the goniometer.

7. Upper Leg Abduction.[24] The goniometer was placed on the right leg above the knee. The subject stood erect with feet together and faced an upright support about 30.5 cm (1 ft) in front of him which he grasped with both hands. The goniometer was set to zero. The subject raised his right leg sideward and up as far as possible while keeping the leg straight and the angular displacement, in degrees, was read from the goniometer.

8. Upper Leg Backward Extension.[34] The goniometer was placed on the right leg above the knee. The subject stood erect with feet together and faced an upright support about 30.5 cm (1 ft) in front of him which he grasped with both hands. The goniometer was set to zero. The right leg was then raised backward as far as possible, with the knee being kept stiff, and the angular displacement, in degrees, was read from the goniometer.

9. Ventral-Dorsal Head Flexion.[34] With hands clasped behind the back of a chair, the seated subject moved his head as far forward as possible and the goniometer, positioned on the right side of the head, was set to zero. He then moved his head as far back as possible and the angular displacement was read, in degrees, from the goniometer.

10. Head Rotation.[34] The goniometer was placed on top of the head. The subject bent at the waist so that his head and chest were parallel to the floor. He grasped the seat of a chair to maintain this position. He rotated his head as far left as possible, and the goniometer was set to zero. He then rotated his head as far right as possible and the angular displacement was read, in degrees, from the goniometer.

11. Pursuit Rotor.[35] This standard tracking task involved visual-motor coordination. The subject was required to keep the tip of a stylus, which was held in the preferred hand, in contact with a small moving target. The target was a flat disc which was 1.9 cm (0.75 in.) in diameter and was embedded in the surface of a turntable. The stylus tip was 0.3 cm (0.12 in.) in diameter. The disc was located 36.5 cm (1.44 in.) from the edge of the turntable which was 25.5 cm (10.04 in.) in diameter and rotated at a speed of 60 rev/min. Contact of the stylus with the target activated a standard stop clock and provided the measure of time-on-target accurate to 0.01 second. The subject was given four trials on the Pursuit Rotor, each lasting 30 seconds, with a rest interval of 30 seconds between the trials. The score was the total time-on-target summed over the four trials. Therefore, the maximum score possible was 120 seconds.

12. O'Connor Finger Dexterity Test.[36] In this test of manual dexterity, the subject was required to put three pins in each of 20 holes using only one hand. The pins were 2.5 cm (0.98 in.) long and 0.1 cm (0.04 in.) in diameter. The holes were 0.5 cm (0.20 in.) in diameter. The score was the time required, read to the nearest 0.01 second, to complete the task.

13. Purdue Pegboard Assembly Test.[37] In this test of manual dexterity, the subject was required to construct 12 pin-washer-collar-washer assemblies in a pegboard using both hands simultaneously. The score was the time required, read to the nearest 0.01 second, to complete the task.

14. Railwalk.[38] This was a test of coordination involving several sensorimotor groups. A rail, 365 cm (143.70 in.) long and 1.90 cm (0.75 in.) thick, was marked at intervals of 1.0 cm (0.39 in.). While grasping his hands behind his back, the subject was to walk the rail in heel-to-toe fashion. The score was the distance to the nearest 1 cm from the start of the rail, where the heel was initially positioned, to the toe of the last foot that remained on the rail when balance was lost.

In addition to employing this task battery to obtain quantitative performance data, a questionnaire was administered to the subjects to elicit their opinions regarding the extent to which the clothing being worn may have hindered their performance on the body mobility and the psychomotor tasks. The subjects were also asked to rate a number of clothing design characteristics and potential clothing problem areas with regard to the degree of performance impairment that they may have represented. In addition, the subjects rated the clothing on scales consisting of pairs of bipolar adjectives.

A copy of the questionnaire is included in Appendix E. A review of it reveals that it is divided into five sections. After the performance of each series of body mobility tasks, the subjects completed Section Ia and Sections II through IV. Section Ib and Sections II through IV were completed after the performance of each series of psychomotor tasks. The subjects completed only those portions of Sections II and III of the questionnaire that pertained to the particular clothing items they were wearing as they executed the body mobility or the psychomotor tasks. Subjects were required to respond twice to Section V, the last section of the questionnaire, once after they had completed all testing involving the mobility tasks and again after they had completed all testing

involving the psychomotor tasks. Here, they were to select the one item out of all those worn that had hindered performance to the greatest extent.

Procedure. Data collection efforts related to the body mobility tasks were completed prior to the initiation of data collection for the psychomotor tasks. To achieve the purposes of Investigations I through V, the subjects performed body mobility tasks under 12 clothing conditions. The order in which the clothing conditions were tested was not based on the ordering of the investigations. Instead, six random sequences of the 12 clothing conditions were generated. Subjects were assigned in pairs to five of the sequences and one subject was assigned to the sixth sequence.

On the day prior to the beginning of body mobility testing, each subject was familiarized with the tasks and with the questionnaire. The subject then participated in one, 1.5-hour session per day for six days. At each session, the subject performed the body mobility tasks and completed the questionnaire twice, once under each of two clothing conditions. The time required to perform all trials on all 10 mobility tasks for a single clothing condition was approximately 15 minutes. There was a 15-minute rest period between exposures to the two conditions. The subject wore a T-shirt, shorts, and standard leather combat boots throughout the session and donned additional clothing items appropriate to the particular condition being tested. The pairs of subjects assigned to the same random sequence of conditions participated in the same sessions and one man was tested alone. Data collection was carried out in a climatic chamber maintained at 15.6°C (60°F).

After a subject's body mobility testing had been completed, he practiced the four psychomotor tasks. The practice phase extended over two days and included one session per day. A session consisted of four trials on each of the tasks, a 15-minute break, and another four trials on each of the tasks. During practice, the men wore their regular duty uniforms which consisted of the BDU coat and trousers and combat boots. The temperature in the climatic chamber was maintained at 15.6°C (60°F).

The subject then participated in one, 2.5-hour test session per day for four days. During this time, the subject performed the psychomotor tasks under 14 clothing conditions. Six random sequences of the clothing conditions were generated and, as was done for the mobility testing, subjects were assigned in pairs to five of the sequences and one subject was assigned to the sixth sequence. Again, the pairs of subjects assigned to the same random sequence were tested at the same sessions and one man was tested alone.

During the first two sessions, the subject performed the psychomotor tasks and completed the questionnaire three times, once under each of three clothing conditions. Four clothing conditions were tested during each of the last two sessions. The time required to complete all psychomotor tasks under a single clothing condition was approximately 20 minutes. There was a 15-minute rest period between exposures to the clothing conditions. Throughout the four sessions, the subject wore a T-shirt, shorts, and combat boots, donning other

clothing items appropriate to the condition being tested. The sessions were conducted in a climatic chamber at an ambient temperature of 15.6°C (60°F).

After completion of all data collection, a number of statistical analyses were performed on each body mobility and each psychomotor task in order to address the objectives of the five investigations included in this phase of the study. The raw data used in analyses of the 10 body mobility tasks and the Railwalk were the mean scores obtained by summing over the four trials on each task that a subject performed. On the O'Connor and the Purdue Tests, the raw data were the scores obtained on the single trial administered. The raw data used in analyses of the Pursuit Rotor were the subjects' total times-on-target, summed over the four, 30-second trials.

The particular clothing conditions and the number of conditions contrasted using statistical techniques varied among the five investigations. However, the statistical test performed in all instances in which only two clothing conditions were to be compared was a t test for small correlated samples.[39] This was carried out to determine whether or not the means for the two conditions, calculated over subjects, differed significantly ($p<.05$). When three or more clothing conditions were to be compared, a repeated measures analysis of variance of the form Subjects x Clothing was applied to the raw data. The analysis of variance was performed on a Univac 1106 computer using BMDP-81 program P8V.[21] If the analysis yielded a significant main effect of clothing ($p<.05$), a Newman-Keuls multiple comparison test was performed to contrast the means for the clothing conditions, with the means being calculated over subjects.[40]

Questionnaire responses were also analyzed. The questionnaire data acquired during the body mobility testing were treated separately from the data acquired during the psychomotor testing. For both sets of data, the responses to each question under each clothing condition were compiled and summarized. Numerical values were assigned to the points on rating scales and median ratings were computed over subjects. The summarized data were then grouped on the basis of the clothing conditions relevant to each of the five investigations. In those instances in which only two clothing conditions were to be compared, the Wilcoxon matched-pairs signed-ranks test was performed on the subjects' ratings.[41] When three or more conditions were to be contrasted, the Friedman two-way analysis of variance was used to test for differences among the rank orderings of the subjects' ratings.[41]

Investigation I. Comparison of MOPP IV With the BDU

Clothing conditions and tasks. Two clothing conditions were compared in this investigation, the BDU coat and trousers and the complete chemical protective system, designated as the MOPP IV level of protection. The subjects wore the MOPP IV attire over a T-shirt and gym shorts. The BDU was also worn over a T-shirt and shorts. Combat boots were used as the footwear.

The subjects performed the body mobility and the psychomotor coordination tasks while outfitted in the BDU and while outfitted in the complete chemical protective system.

Results. The mean scores on each body mobility and each psychomotor task for the BDU and the MOPP IV conditions are presented in Table 12. The results of the t tests conducted to compare the means for the two clothing conditions are also included in the table. The means indicate that performance in the BDU was superior to that in MOPP IV on all mobility tasks except Standing Trunk Flexion and Upper Arm Forward Extension. However, the means for the BDU were significantly better than the means for MOPP IV only on the two mobility tasks involving head movements, Ventral-Dorsal Head Flexion and Head Rotation (Table 12). On the other hand, a significant difference between the means was obtained on all four psychomotor tasks, and, on each task, performance in the BDU was superior to that in MOPP IV (Table 12).

Summary data from Sections I and IV of the questionnaire are presented in Tables 13 and 14, respectively. Median ratings are included in the tables along with the results of the Wilcoxon tests (T) and the N associated with each Wilcoxon test. The median ratings in Table 13 for the extent to which the BDU interfered with performance of each mobility task and each psychomotor task (Section I of the questionnaire) are quite low indicating that, in the subjects' opinions, the BDU had only a slight negative effect or no negative effect at all on their performance. The median ratings for MOPP IV are generally higher than those for the BDU: Some medians exceed the level of moderate performance impairment and two medians, those for the O'Connor and the Purdue Tests, exceed the level of considerable impairment. The results of the Wilcoxon tests indicate that the ratings that the subjects assigned to the two clothing conditions differed significantly for all tasks except Standing Trunk Flexion and Upper Arm Abduction and Forward Extension (Table 13).

The medians for the bipolar adjectives in Section IV of the questionnaire are presented in Table 14. Included there are medians calculated from the subjects' ratings during mobility testing and their ratings during psychomotor testing. The median ratings for the BDU associated with body mobility testing tend to lie between the neutral and the somewhat positive points on the scale, whereas the medians for the MOPP IV condition tend to lie between the neutral and the somewhat negative points on the scale. The Wilcoxon tests performed on the subjects' ratings acquired during mobility testing yielded a number of significant differences between the two clothing conditions, including differences in comfort, fit, and thermal sensations (Table 14).

For the psychomotor testing, the median ratings of the BDU generally lie around the somewhat positive point on the scale; the medians for MOPP IV are between the neutral and the very negative points on the scale. The Wilcoxon tests performed on the psychomotor data yielded significant differences between the two clothing conditions on all bipolar dimensions except flimsiness-sturdiness (Table 14).

On the bipolar dimensions, the medians associated with the psychomotor testing are generally more extreme than the medians for the mobility testing. That is, typically the BDU was rated more positively and the MOPP IV condition was rated more negatively on a bipolar dimension during psychomotor testing than during body mobility testing (Table 14).

TABLE 12. Mean Scores for Body Mobility and Psychomotor Tasks Under BDU and MOPP IV Conditions

Task	Clothing Condition		t[a]
	Body Mobility		
1. Standing Trunk Flexion (cm)	MOPP IV 2.70	BDU 2.83	0.16
2. Upper Arm Abduction (deg.)	BDU 150.23	MOPP IV 147.02	1.25
3. Upper Arm Forward Extension (deg.)	MOPP IV 150.54	BDU 149.05	0.34
4. Upper Arm Backward Extension (deg.)	BDU 41.14	MOPP IV 38.52	1.17
5. Upper Leg Flexion (deg.)	BDU 76.61	MOPP IV 75.09	0.53
6. Upper Leg Forward Extension (deg.)	BDU 65.66	MOPP IV 62.09	1.62
7. Upper Leg Abduction (deg.)	BDU 53.91	MOPP IV 51.39	1.87
8. Upper Leg Backward Extension (deg.)	BDU 40.95	MOPP IV 39.73	0.74
9. Ventral-Dorsal Head Flexion (deg.)	BDU 140.86	MOPP IV 120.25	5.71***
10. Head Rotation (deg.)	BDU 155.80	MOPP IV 106.32	9.20***
	Psychomotor Coordination		
11. Pursuit Rotor (sec)	BDU 103.66	MOPP IV 95.32	2.91*
12. O'Connor Finger Dexterity (sec)	BDU 74.23	MOPP IV 105.72	9.99**
13. Purdue Pegboard Assembly (sec)	BDU 52.42	MOPP IV 170.55	4.57**
14. Railwalk (cm)	BDU 201.80	MOPP IV 134.98	4.79***

NOTE: Clothing conditions connected by the same line are not significantly different ($p > .05$).

[a]For Standing Trunk Flexion, $df = 9$; for all other tasks, $df = 10$.

*$p < .02$
**$p < .01$
***$p < .001$

TABLE 13. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under BDU and MOPP IV Conditions

Task	Clothing Condition BDU	MOPP IV	T	(N)
Body Mobility				
1. Standing Trunk Flexion	1.4	1.2	10.0	(6)
2. Upper Arm Abduction	1.6	2.0	3.5	(6)
3. Upper Arm Forward Extension	1.2	1.8	3.0	(6)
4. Upper Arm Backward Extension	1.6	2.4	3.0*	(7)
5. Upper Leg Flexion	1.4	2.1	0.0**	(7)
6. Upper Leg Forward Extension	1.3	2.4	0.0***	(9)
7. Upper Leg Abduction	1.3	2.0	0.0**	(7)
8. Upper Leg Backward Extension	1.3	2.2	0.0*	(6)
9. Ventral-Dorsal Head Flexion	1.0	3.0	0.0***	(10)
10. Head Rotation	1.0	3.6	0.0***	(11)
Psychomotor Coordination				
11. Pursuit Rotor	1.1	3.2	0.0***	(9)
12. O'Connor Finger Dexterity	1.0	4.1	0.0***	(11)
13. Purdue Pegboard Assembly	1.1	4.6	0.0***	(11)
14. Railwalk	1.2	3.8	0.0***	(11)

NOTE: Subjects rated the extent to which performance on each task was impaired by the clothing being worn according to the following scale: 1 = not at all; 2 = slightly; 3 = moderately; 4 = considerably; 5 = extremely.

*$p<.05$
**$p<.02$
***$p<.01$

TABLE 14. Median Ratings of Bipolar Dimensions for Body Mobility and Psychomotor Tasks Under BDU and MOPP IV Conditions

Bipolar Dimension	Clothing Condition BDU	MOPP IV	T	(N)
		Body Mobility		
Uncomfortable-Comfortable	+1.3	-1.0	3.5**	(10)
Inflexible-Flexible	0.0	-1.0	8.0*	(10)
Heavy-Light	+0.2	-0.9	0.0***	(9)
Binding-Free moving	-0.6	-1.1	0.0**	(7)
Hot-Cool	-0.4	-1.7	0.0***	(9)
Poorly balanced-Well balanced	+0.7	-0.9	7.5*	(10)
Tight-Loose	-0.6	-0.4	14.0	(7)
Flimsy-Sturdy	+0.6	+0.4	9.5	(6)
Poorly fitted-Well fitted	+0.9	-0.2	0.0*	(6)
Hard to work in-Easy to work in	0.0	-1.1	9.5	(9)
Function poorly-Function well	+1.0	0.0	2.5	(6)
Dislike-Like	+1.2	-0.8	6.5	(8)
		Psychomotor Coordination		
Uncomfortable-Comfortable	+1.7	-1.6	0.0***	(11)
Inflexible-Flexible	+1.4	-1.1	0.0***	(11)
Heavy-Light	+0.7	-1.3	0.0***	(10)
Binding-Free moving	+0.9	-0.9	0.0***	(9)
Hot-Cool	+0.3	-1.2	0.0***	(10)
Poorly balanced-Well balanced	+1.1	-1.6	0.0***	(10)
Tight-Loose	+0.2	-0.4	0.0***	(6)
Flimsy-Sturdy	+1.0	+0.7	11.0	(9)
Poorly fitted-Well fitted	+1.1	-0.8	0.0***	(8)
Hard to work in-Easy to work in	+1.1	-1.8	0.0***	(11)
Function poorly-Function well	+1.2	-1.3	0.0***	(10)
Dislike-Like	+1.1	-1.6	0.0***	(9)

NOTE: Possible scores range from -3 to +3 with -3 indicating the extreme for the first (negative) word in the adjective pair, 0 indicating neutral, and +3 indicating the extreme for the second (positive) word in the adjective pair.

*p<.05
**p<.02
***p<.01

Discussion. Based upon the results of this investigation, it appears that gross movements of the torso, the arms, and the legs are, at most, minimally affected by the use of the complete chemical protective clothing system, the MOPP IV level of protection, compared with the use of a common field duty uniform, the BDU coat and trousers. However, movements of the head were significantly restricted in MOPP IV and this clothing system also had a deleterious effect on performance of tasks requiring visual-motor coordination or manual dexterity. Of the four psychomotor tasks, the Purdue Pegboard Assembly Test, a test involving dextrous manipulations and coordination of movements of both hands, was most severely affected by the protective clothing system. The mean time to complete this task was more than three times longer when MOPP IV attire was worn than when the BDU was used.

The responses to the questionnaire were a reflection that the subjects were aware of the restriction that MOPP IV attire imposed on their head movements and the deleterious effects of this attire on psychomotor coordination. They assigned higher ratings to the MOPP IV condition, indicating greater performance impairment, on the two tests involving head movements and the four psychomotor tasks than they did on the other tasks that they performed. The ratings that they gave to the BDU were quite low indicating that the subjects felt there was little or no impairment of their performance on any task due to this uniform.

The subjects also generally rated the BDU positively and the MOPP IV attire negatively on a number of bipolar dimensions that were selected to describe characteristics of clothing. Their ratings reflected the greater difficulties experienced performing the psychomotor tasks than the body mobility tasks in MOPP IV attire to the extent that, in most instances, the rating given a bipolar dimension during psychomotor testing was generally more negative than the rating given the same dimension during body mobility testing.

In investigations to be reported subsequently, the components of the chemical protective clothing system will be examined to determine the particular protective items comprising MOPP IV that had a negative impact on task performance or were found by the subjects to pose a hindrance to performance.

Investigation II. Comparison of the CP Overgarment With Other Torso Clothing

Clothing conditions and tasks. Three clothing conditions were compared in this investigation: the T-shirt and gym shorts (Shorts), the BDU coat and trousers (BDU), and the chemical protective overgarment coat and trousers (OG). When the BDU and the overgarment were tested, they were worn over the T-shirt and shorts. Combat boots were used throughout as the footwear.

The subjects performed the body mobility and the psychomotor coordination tasks while outfitted in each of the three clothing conditions.

Results. The mean scores on each body mobility and each psychomotor task for the shorts, the BDU, and the CP overgarment conditions are presented in Table 15. The *F* ratios for the main effect of clothing obtained in the analyses of variance performed on the tasks are also included.

TABLE 15. Mean Scores for Body Mobility and Psychomotor Tasks Under Shorts, BDU, and Overgarment Conditions

Task	Clothing Condition			F^a
	Body Mobility			
1. Standing Trunk Flexion (cm)	Shorts 2.14	OG 2.32	BDU 2.83	<1.00
2. Upper Arm Abduction (deg.)	Shorts 157.66	BDU 150.23	OG 142.93	13.54***
3. Upper Arm Forward Extension (deg.)	Shorts 155.98	OG 152.20	BDU 149.05	2.53
4. Upper Arm Backward Extension (deg.)	Shorts 43.50	BDU 41.14	OG 37.68	2.66
5. Upper Leg Flexion (deg.)	Shorts 84.20	BDU 76.61	OG 74.11	9.89**
6. Upper Leg Forward Extension (deg.)	Shorts 68.52	BDU 65.66	OG 64.36	1.80
7. Upper Leg Abduction (deg.)	Shorts 60.61	BDU 53.91	OG 52.07	6.30*
8. Upper Leg Backward Extension (deg.)	Shorts 42.66	BDU 40.95	OG 40.54	<1.00
9. Ventral-Dorsal Head Flexion (deg.)	BDU 140.86	OG 139.18	Shorts 137.11	<1.00
10. Head Rotation (deg.)	BDU 155.80	Shorts 150.73	OG 147.93	3.05
	Psychomotor Coordination			
11. Pursuit Rotor (sec)	BDU 103.66	Shorts 100.90	OG 100.31	<1.00
12. O'Connor Finger Dexterity (sec)	OG 71.58	Shorts 73.32	BDU 74.23	<1.00
13. Purdue Pegboard Assembly (sec)	BDU 52.42	Shorts 52.66	OG 53.86	<1.00
14. Railwalk (cm)	Shorts 207.66	BDU 201.80	OG 168.86	2.60

NOTE: Clothing conditions connected by the same line are not significantly different ($p > .05$)

^{a}df = 2,20 *$p < .01$ **$p < .005$ ***$p < .001$

It can be seen in Table 15 that the means for the shorts condition are superior to those for the other two conditions on all body mobility tasks except Ventral-Dorsal Head Flexion and Head Rotation. On these two tasks, the highest means are for the BDU condition. However, a significant main effect of clothing was obtained on only three of the mobility tasks. These were Upper Arm Abduction, Upper Leg Flexion, and Upper Leg Abduction. Newman-Keuls multiple comparison tests were performed on the means for these three tasks and the results of the tests are indicated in Table 15.

On Upper Arm Abduction, the mean score achieved when the T-shirt and shorts were worn was significantly better than the means for the other two conditions, whereas the mean associated with the overgarment was significantly worse than the means for the other conditions. For Upper Leg Flexion and Abduction, the relationships among the three clothing conditions were similar to each other. On these two tasks, the mean score for the shorts condition was significantly better than the means associated with the BDU and with the overgarment. However, the means for the BDU and the overgarment conditions did not differ significantly from each other (Table 15).

With regard to the psychomotor coordination tasks, the means for the clothing conditions closely approximate each other on all tasks except the Railwalk. Here, the mean for the overgarment condition is substantially lower than those for the shorts and the BDU conditions (Table 15). However, the analyses of variance did not yield a significant main effect of clothing on the Railwalk or on the other three psychomotor coordination tasks.

Summary data from Section II of the questionnaire are presented in Table 16. Included in the table are median ratings of the importance of some design characteristics of torso clothing in interfering with performance of the body mobility and the psychomotor tasks. The results of the Friedman two-way analyses of variance by ranks (χ_r^2) are also presented in Table 16. The median values of 1.0 for the shorts condition indicate that the subjects found that the design characteristics of this condition were of no importance in interfering with performance. The medians for the BDU condition tend to be slightly higher than those for the shorts condition, whereas the medians for the overgarment condition tend to be slightly higher than those for the BDU. The differences among the clothing conditions are greater for the ratings associated with body mobility testing than they are for the ratings associated with psychomotor testing (Table 16).

For the BDU, the design characteristic with the highest median, a value of 1.6, is armhole opening fit and this highest median was calculated from ratings given the BDU during body mobility testing. For the protective overgarment, several design characteristics have medians associated with body mobility testing that approximate 2.0, indicating that the subjects considered these characteristics to be of some little importance in interfering with their performance. The characteristics are garment bulk, sleeve length and cuff fit of the coat, and crotch length of the trousers. The highest median for the overgarment, a value of 2.3, is for the characteristic of shoulder flexibility (Table 16). Again, the median was calculated from ratings associated with body mobility testing.

TABLE 16. Median Ratings of Torso Clothing Design Characteristics for Body Mobility and Psychomotor Tasks Under Shorts, BDU, and Overgarment Conditions

Design Characteristic	Clothing Condition Shorts	BDU	OG	X_r^2 [a]
		Body Mobility		
Garment bulk	1.0	1.2	1.9	6.32*
Garment weight	1.0	1.2	1.4	2.59
Collar flexibility	1.0	1.1	1.4	2.59
Collar height	1.0	1.1	1.4	2.59
Shoulder flexibility	1.0	1.4	2.3	12.32**
Armhole opening fit	1.0	1.6	1.6	4.95
Sleeve cuff flexibility	1.0	1.2	1.3	1.68
Sleeve length	1.0	1.4	1.9	6.04*
Sleeve cuff fit	1.0	1.4	1.9	4.91
Chest flexibility	1.0	1.4	1.7	4.68
Waist flexibility	1.0	1.2	1.2	1.27
Waist fit	1.0	1.3	1.3	3.89
Trouser length at crotch	1.0	1.4	2.0	4.41
Upper leg fit	1.0	1.3	1.2	0.95
Fit at knee	1.0	1.4	1.3	2.86
Lower leg fit	1.0	1.1	1.2	1.14
Trouser leg length	1.0	1.3	1.3	2.23
Ankle flexibility	1.0	1.1	1.0	0.00
		Psychomotor Coordination		
Garment bulk	1.0	1.2	1.6	3.68
Garment weight	1.0	1.0	1.3	1.77
Collar flexibility	1.0	1.0	1.0	0.14
Collar height	1.0	1.0	1.1	4.41
Shoulder flexibility	1.0	1.1	1.1	0.54
Armhole opening fit	1.0	1.1	1.1	0.54
Sleeve cuff flexibility	1.0	1.0	1.0	0.14
Sleeve length	1.0	1.0	1.3	1.77
Sleeve cuff fit	1.0	1.0	1.3	1.77
Chest flexibility	1.0	1.0	1.0	0.14
Waist flexibility	1.0	1.0	1.0	0.14
Waist fit	1.0	1.0	1.0	0.18
Trouser length at crotch	1.0	1.1	1.0	0.41
Upper leg fit	1.0	1.0	1.0	0.14
Fit at knee	1.0	1.1	1.0	0.41
Lower leg fit	1.0	1.0	1.0	0.18
Trouser leg length	1.0	1.1	1.1	0.59
Ankle flexibility	1.0	1.1	1.1	0.14

NOTE: Subjects rated the importance of each design characteristic in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a] *df*=2; *$p<.05$; **$p<.01$

As can be seen in Table 16, there were three design characteristics for which the Friedman analyses yielded significant differences among the rank orderings of the ratings that the subjects assigned to the clothing conditions. These significant findings were also for the body mobility testing, rather than the psychomotor testing. The characteristics are garment bulk, shoulder flexibility, and sleeve length. The overgarment condition has the highest median rating on each of these characteristics followed by the BDU condition.

The medians for the bipolar adjectives in Section IV of the questionnaire are presented in Table 17. The results of the Friedman analyses are also included. Significant differences among the rank orderings of the ratings of the clothing conditions were obtained in each of these analyses, except the tests performed on the bipolar dimension of flimsiness-sturdiness. Generally, the shorts condition has the most positive ratings, followed by the BDU condition, and then the overgarment condition. However, the medians for the BDU and the overgarment do tend to be more similar than are the medians for the BDU and the shorts (Table 17).

On the mobility testing, the largest difference between the median values for the BDU and the overgarment is on the bipolar dimension of uncomfortable-comfortable. On the psychomotor testing, there is also a relatively large difference between these two conditions in the medians for the comfort dimension, along with the flexibility dimension (Table 17).

Discussion. The findings from this investigation revealed that there was little difference between the BDU and the protective overgarment in terms of their relative effects on gross body mobility and psychomotor coordination. Indeed, performance levels achieved when only the T-shirt and gym shorts were worn were, in most instances, not significantly superior to those achieved in the BDU or in the overgarment.

One task on which the scores for the BDU were significantly better than the scores for the protective overgarment was Upper Arm Abduction. The mean score for the BDU was 5% higher than that for the overgarment. Upper Arm Abduction was also one of the few tasks in which performance in T-shirt and shorts was significantly superior to performance in the BDU or the overgarment, with the mean for the T-shirt and shorts being 5% higher than the mean for the BDU and 9% higher than the mean for the overgarment. This task required the raising of both arms in the body's frontal plane. On the body itself, the arm-shoulder complex of joints is the origin of the angle generated as the arm is abducted. However, in this investigation, the upper torso was clothed in sleeved garments. Therefore, the body-clothing relationship must be taken into account in assessing Upper Arm Abduction capabilities.

It is likely that armhole opening length was the principal dimensional characteristic of the upper torso clothing that affected performance on this task. On the clothing, the origin for the angle formed during Upper Arm Abduction is the lowest point of the armhole opening. As the distance between this origin and the body's origin for the formation of the angle increases, Upper Arm Abduction is decreased. To permit unrestricted arm movement in the body's frontal plane, the inner surfaces of the arm and the sleeve must remain

TABLE 17. Median Ratings of Bipolar Dimensions for Body Mobility and Psychomotor Tasks Under Shorts, BDU, and Overgarment Conditions

Bipolar Dimension	Clothing Condition Shorts	BDU	OG	X_r^2[a]
Body Mobility				
Uncomfortable-Comfortable	+2.7	+1.3	-0.2	11.77***
Inflexible-Flexible	+2.7	0.0	-0.4	15.27****
Heavy-Light	+2.7	+0.2	0.0	9.86***
Binding-Free moving	+2.7	-0.6	-0.3	12.41***
Hot-Cool	+2.4	-0.4	-0.3	10.77***
Poorly balanced-Well balanced	+2.6	+0.7	0.0	13.68***
Tight-Loose	+1.3	-0.6	-0.1	6.04*
Flimsy-Sturdy	+0.2	+0.6	+0.6	4.09
Poorly fitted-Well fitted	+2.2	+0.9	+0.2	9.59***
Hard to work in-Easy to work in	+2.7	0.0	0.0	16.41****
Function poorly-Function well	+2.6	+1.0	+0.9	11.09***
Dislike-Like	+2.8	+1.2	+0.2	12.41***
Psychomotor Coordination				
Uncomfortable-Comfortable	+2.7	+1.7	+0.3	14.77****
Inflexible-Flexible	+2.4	+1.4	0.0	12.68***
Heavy-Light	+2.4	+0.7	-0.3	13.95****
Binding-Free moving	+2.6	+0.9	0.0	13.95****
Hot-Cool	+2.2	+0.3	-0.2	12.68***
Poorly balanced-Well balanced	+2.0	+1.1	+0.4	7.14*
Tight-Loose	+1.8	+0.2	+0.2	7.95**
Flimsy-Sturdy	+0.1	+1.0	+0.9	4.14
Poorly fitted-Well fitted	+2.4	+1.1	+0.6	11.77***
Hard to work in-Easy to work in	+2.8	+1.1	-0.2	15.27****
Function poorly-Function well	+2.4	+1.2	+0.7	13.27***
Dislike-Like	+2.4	+1.1	+0.6	13.14***

NOTE: Possible scores range from -3 to +3 with -3 indicating the extreme for the first (negative) word in the adjective pair, 0 indicating neutral, and +3 indicating the extreme for the second (positive) word in the adjective pair.

[a] $df=2$

*$p<.05$
**$p<.02$
***$p<.01$
****$p<.001$

essentially parallel to each other during arm movement. Lengthening of the armhole opening results in the formation of an acute angle between these two surfaces as the arm is abducted. The more limited the circumference of the sleeve and the extensibility of the fabric, the more the dorsal surface of the upper arm will be bound by the sleeve, and arm movement will thereby be restricted.

The armhole openings of the protective overgarment are longer than those of the BDU because the overgarment is designed to be worn as the outermost clothing layer over the BDU or other torso clothing. Likewise, the armhole openings of the BDU are longer than those of a T-shirt because the latter is worn next to the skin. Thus, the armhole openings of the overgarment extend farther down the side of the body, below the arm scye, than do the armholes of the BDU which, in turn, extend farther below the arm scye than the armholes of a T-shirt.

There is a factor that may have interacted with armhole dimensions to affect Upper Arm Abduction. This is the ease with which the sleeves of the clothing ride up the arm as the arm is abducted. The sleeves of the T-shirt are short. They are also made of a stretchable, cotton-knit material that should not have imposed restrictions on arm-shoulder movements. In this study, the sleeves of the BDU were worn rolled up to the upper arm. However, the sleeves of the overgarment extended to the wrist and their elasticized cuffs may have inhibited the sleeve from moving up the arm and thereby limited the degree to which the arm could be abducted.

On the questionnaire, the design characteristic with the highest median rating for interfering with body mobility was the shoulder flexibility of the protective overgarment. The fit of the sleeve cuffs and the length of the sleeves were other design characteristics for which the overgarment received relatively high negative ratings compared with the ratings that the subjects assigned to the shorts and the BDU. Thus, the subjects may have recognized that Upper Arm Abduction was restricted to a greater extent by the protective overgarment than by the other clothing conditions.

In Investigation I, no significant difference in Upper Arm Abduction scores was obtained when performance in the complete chemical protective system, the MOPP IV attire, was contrasted with performance in the BDU. Therefore, it is somewhat surprising to find in this investigation that performance in the overgarment, worn without other components of the protective system, was significantly worse than performance in the BDU. Use of the overgarment alone, however, resulted in scores for Upper Arm Abduction that were inferior to those for the MOPP IV attire. The mean score for the overgarment was 4° lower than the mean for MOPP IV, and 7° lower than the mean for the BDU.

If, as appears to be the case, the extent to which the arm could be abducted was affected by the length of the armhole opening on the clothing, it is possible that use of the mask hood, a component of the MOPP IV level of protection, alleviated some of the restriction in arm movement imposed by the overgarment's relatively long armhole opening. The straps on the hood pass under the arm scye. These may have served to raise the garment's origin of the

angle formed during abduction from the lowest point of the armhole opening, moving it closer to the arm scye and thus closer to the origin of the angle on the body.

In this investigation, as in Investigation I, Forward and Backward Upper Arm Extension, the other arm-shoulder flexibility tasks, were not significantly affected by the clothing worn. The arm movements required on both these tasks were in the body's sagittal plane. Unlike abduction of the upper arm, Forward and Backward Extension were not likely to be affected by the armhole opening characteristics of the clothing used in this investigation because the arm movements required were parallel to the plane of the armhole opening. However, if a garment had been made of a rigid material and the plane of the armhole openings had been offset from the body's plane, it is likely that reduction in arm extension capabilities would have resulted. In a study of armor vests, which were rather rigid because they were made of many plies of ballistic filler material, Bensel et al.[27] did find that both Forward and Backward Upper Arm Extension scores were lower when the vests were worn than they were when a regular duty uniform was being worn.

In addition to the Arm Abduction task, the clothing variable had a significant effect on two of the four tasks included in this investigation which involved movement of the leg from the hip. These were Upper Leg Flexion and Abduction. The tasks that were not significantly affected by the clothing conditions were Upper Leg Forward Extension and Upper Leg Backward Extension. These two tasks required that the leg be kept straight at the knee and thrust forward or back in the body's sagittal plane. Upper Leg Flexion involved movement in the same body plane, but the leg was bent at the knee and the upper leg was raised toward the chest as far as possible. Therefore, Upper Leg Flexion would be expected to be more sensitive than Upper Leg Forward or Backward Extension to the binding of the ventral or dorsal surfaces of the upper leg by the clothing. The highest mean score on Upper Leg Flexion, which was achieved when only the T-shirt and shorts were worn, was significantly better than the scores for the BDU and the protective overgarment. There was no significant difference between the means for the BDU and the overgarment. Given these relationships among the clothing conditions, it appears likely that the BDU and the overgarment trousers did bind the upper leg, and possibly the knee, during flexion, an effect that would not be expected with the shorts because they cover little of the upper leg.

For Upper Leg Abduction, the relationships among the clothing conditions were similar to these obtained for Upper Leg Flexion. That is, performance with the shorts and T-shirt was significantly superior to performance with the BDU and the overgarment, and the scores for the BDU and the overgarment did not differ significantly from each other. Upper Leg Abduction required the raising of the leg in the body's frontal plane with the leg being kept straight at the knee. Clothing could limit the extent of this movement by binding the lateral surface of the upper leg. This appears to have been the case given that performance in the shorts was superior to performance in either of the garments with long trouser legs.

Among the design characteristics related to lower torso clothing that the subjects rated on the questionnaire were the fit at the upper leg and at the knee. The ratings of the extent to which these characteristics may have interfered with body mobility were only slightly higher for the BDU and the protective overgarment than they were for the shorts. The small differences among the clothing conditions may be an indication that the subjects did not experience extensive binding of the leg by the trousers, although the scores on Upper Leg Flexion and Abduction indicated that this probably did occur. A trouser characteristic that was given relatively high negative ratings was the crotch length of the overgarment. The crotch of the overgarment is longer than that of the BDU or the shorts to allow the wearing of other lower torso clothing under the overgarment trousers. However, this dimensional difference among the clothing items included in the present investigation had no obvious effect on the execution of the leg movements, insofar as performance while wearing the overgarment was not significantly poorer than performance while wearing the BDU.

Garment bulk was another design characteristic listed in the questionnaire for which the overgarment received relatively high negative ratings. Unlike the BDU, which is made of a single layer of material, the overgarment is fabricated of several layers, a shell and a laminated liner. There is a greater amount of ease in the overgarment coat and trousers so that these items can be worn as the outermost garments over other clothing items, such as the BDU, and the overgarment coat extends below the waist to the level of the hips. All these factors contributed, no doubt, to the subjects' perception that the overgarment was bulkier than the other garments they wore in this investigation. However, the subjects' scores for Standing Trunk Flexion, a task that has been found to be affected by clothing bulk, or thickness, in the waist area,[28] did not differ significantly as a function of the garment being worn. The mean score for the overgarment was even slightly higher than the mean for the BDU. Thus, although there are differences between the overgarment and the BDU in design and material configuration that had the potential of resulting in trunk flexion being more limited when the overgarment was worn than when the BDU was used, the effects of these differences were not realized in the subjects' performance.

Scores on the two body mobility tasks involving head movements, Ventral-Dorsal Head Flexion and Head Rotation, were also unaffected by the garments being worn. Thus, the stand-up collar on the coat of the protective overgarment did not restrict head movement relative to that achieved when the collarless T-shirt or the BDU coat with its flat collar were worn. In Investigation I, it was found that performance on both the Head Flexion and the Head Rotation tasks was significantly worse in the MOPP IV attire than in the BDU. Given the results of the present investigation, it appears that some MOPP IV component other than the overgarment, undoubtedly the mask with hood, was responsible for the fact that angular displacements of the head were more limited when the chemical protective clothing system was worn than when the BDU was used.

In a similar vein, the present investigation did not yield a significant effect of clothing condition on any of the four tests of psychomotor coordination, although, in Investigation I, performance on each of these tests was significantly worse in MOPP IV than in the BDU. There were indications in the present investigation that the protective overgarment did have a detrimental

effect on performance of the Railwalk. The mean distance traversed when the overgarment was worn was reduced by 16% relative to the mean for the BDU and by 19% relative to the mean for the T-shirt and shorts. In their study of cold weather clothing, Bensel et al.[28] found that Railwalk performance deteriorated as the number of layers of torso clothing was increased. Thus, this task appears to be sensitive to the bulkiness of clothing around the legs. On the other three tests of psychomotor coordination, the means for the three clothing conditions were highly similar to each other indicating that some chemical protective component other than the overgarment was responsible, at least in part, for the relatively poor psychomotor performance in MOPP IV compared with performance in the BDU. The effects of chemical protective items, exclusive of the overgarment, on body mobility and psychomotor coordination will be pursued in the next investigation.

In this examination of the effects of different types of torso clothing, it has been found that performance levels achieved in the protective overgarment generally differ little from those achieved in the BDU. Also, use of either of these garments has little negative impact on body mobility and psychomotor coordination compared with use of the T-shirt and gym shorts. The only task that yielded scores for the overgarment that were significantly worse than those for the BDU was Upper Arm Abduction. The fact that the overgarment is loose-fitting appears to have contributed toward the degradation in Upper Arm Abduction performance. Although a statistically significant clothing effect was not obtained on the Railwalk, the scores for the overgarment were substantially lower than those for the BDU and for the T-shirt and shorts. Here again the loose fit of the overgarment, and the associated bulkiness of the trousers, may have produced a "hobbling" effect as the subjects tried to take repeated steps along the rail. The fit of the overgarment may also have influenced the subjects' responses on the questionnaire and resulted in the trend toward less positive ratings for the overgarment than for the BDU and the T-shirt and shorts.

The loose fit of the overgarment is inherent in the functional concept employed in designing the garment. It is to be worn as the outermost layer over other clothing, be it a BDU, an armor vest, a field jacket, or a combination of these and additional items. The overgarment was graded such that circumferential dimensions vary from size to size, but linear dimensions do not. For example, the inseam of the size XXX-Small trousers is the same length as the inseam of the size XX-Large. It maybe possible to retain the loose fit of the overgarment while providing soldiers with garments that are more acceptable to them by revising the grading system so that both circumferential and linear dimensions vary with size.

Investigation III. Individual and Combined Effects of CP Items Exclusive of the CP Overgarment

Clothing conditions and tasks. A total of six clothing conditions comprised this investigation. For one of them, the T-shirt, gym shorts, and combat boots were worn. The remaining five conditions consisted of this clothing plus one or more of the following chemical protective items: the mask with hood, the overboots, and the gloves. The conditions and their designations were:

1. T-shirt, shorts (Shorts).
2. T-shirt, shorts, mask with hood (Shorts + Mask).
3. T-shirt, shorts, overboots (Shorts + Boots).
4. T-shirt, shorts, gloves (Shorts + Gloves).
5. T-shirt, shorts, mask with hood, overboots (Shorts + Mask + Boots).
6. T-shirt, shorts, mask with hood, gloves (Shorts + Mask + Gloves).

Each body mobility and psychomotor task was performed under only some of the six conditions. The conditions tested for each task are presented in Table 18. As can be seen in the table, all tasks were performed under the shorts condition. This served as a baseline for determining levels of performance degradation attributable to the wearing of the protective items alone and in combination with each other. In selecting the remaining clothing conditions under which a particular task was to be performed, the nature of the task was considered and those conditions that involved protective items judged to be extraneous to task execution were excluded. For example, leg movements were not performed under clothing conditions in which the mask or the gloves were worn because it was judged unlikely that these items would interfere with the extent to which the leg could be moved.

Results. The mean scores on each body mobility and each psychomotor task for the various clothing conditions are presented in Table 19 and depicted graphically in Figures 4 through 9. For those tasks on which two clothing conditions were compared, the results of the *t* tests for small, correlated samples are included in Table 19, whereas, for those tasks on which three or more conditions were compared, the *F* ratios for the main effects of clothing obtained in the analyses of variance are included. It can be seen in Table 19 that significant differences in performance as a function of the clothing worn were obtained for two of the body mobility tasks, Ventral-Dorsal Head Flexion and Head Rotation, and for two of the psychomotor coordination tasks, the O'Connor and the Purdue Pegboard Assembly Tests. The results of the Newman-Keuls multiple comparison tests performed on the means for these two psychomotor tasks are also presented in Table 19.

Both mobility tasks that required movement of the head were affected similarly by clothing condition (Figure 7). Use of the protective mask with hood resulted in significantly poorer performance than was obtained when only the T-shirt and shorts were worn (Table 19). The two tests of manual dexterity were also affected similarly by clothing condition (Figure 8). The fastest mean times to task completion occurred when the T-shirt and shorts were worn alone and when the mask with hood was used. These scores did not differ significantly from each other. They were significantly better than the mean scores achieved when the gloves were worn with the T-shirt and shorts and when the gloves, as well as the mask with hood, were used. Although the mean for the condition in which the gloves and the mask with hood were worn is somewhat lower than the mean for the condition in which the gloves were used, but the mask with hood was not, the means for these two conditions did not differ significantly from each other (Table 19).

TABLE 18. Tasks Performed Under Each Clothing Condition Included in Investigation III

Task		Clothing Condition					
		Shorts	Shorts + Mask	Shorts + Boots	Shorts + Gloves	Shorts + Mask + Boots	Shorts + Mask + Gloves
	Body Mobility						
1.	Standing Trunk Flexion	o	o				
2.	Upper Arm Abduction	o	o				
3.	Upper Arm Forward Extension	o	o				
4.	Upper Arm Backward Extension	o	o				
5.	Upper Leg Flexion	o		o			
6.	Upper Leg Forward Extension	o		o			
7.	Upper Leg Abduction	o		o			
8.	Upper Leg Backward Extension	o		o			
9.	Ventral-Dorsal Head Flexion	o	o				
10.	Head Rotation	o	o				
	Psychomotor Coordination						
11.	Pursuit Rotor	o	o		o		o
12.	O'Connor Finger Dexterity	o	o		o		o
13.	Purdue Pegboard Assembly	o	o		o		o
14.	Railwalk	o	o	o		o	

TABLE 19. Mean Scores for Body Mobility and Psychomotor Tasks Under Each Condition in Which Shorts and CP Items Were Worn

Task	Clothing Condition[a]				t[b]	F[c]
Body Mobility						
1. Standing Trunk	1	2				
Flexion (cm)	2.14	2.30			0.06	-
2. Upper Arm	1	2				
Abduction (deg.)	157.66	155.77			0.63	-
3. Upper Arm Forward	1	2				
Extension (deg)	155.98	155.52			0.28	-
4. Upper Arm Backward	1	2				
Extension (deg.)	43.50	42.59			0.32	-
5. Upper Leg	3	1				
Flexion (deg.)	85.05	84.20			0.44	-
6. Upper Leg Forward	3	1				
Extension (deg.)	69.89	68.52			0.40	-
7. Upper Leg	1	3				
Abduction (deg.)	60.61	58.66			0.56	-
8. Upper Leg Backward	1	3				
Extension (deg.)	42.66	42.00			0.25	-
9. Ventral-Dorsal	1	2				
Head Flexion (deg.)	137.11	123.30			3.00*	-
10. Head Rotation (deg.)	1	2				
	150.73	118.89			9.23**	-
Psychomotor Coordination						
11. Pursuit Rotor (sec)	2	1	6	4		
	101.39	100.90	96.53	95.19	-	2.76
12. O'Connor Finger	2	1	6	4		
Dexterity (sec)	73.27	73.32	111.27	120.30	-	29.84**
13. Purdue Pegboard	2	1	6	4		
Assembly (sec)	52.30	52.66	165.01	174.67	-	18.70**
14. Railwalk (cm)	1	3	5	2		
	207.66	188.86	169.98	169.20	-	2.44

NOTE: Clothing conditions connected by the same line are not significantly different ($p > .05$).

[a] 1=Shorts; 2=Shorts + Mask; 3=Shorts + Boots; 4=Shorts + Gloves; 5=Shorts + Mask + Boots; 6=Shorts + Mask + Gloves. [b] $df = 10$ [c] $df = 3,30$

* $p < .02$ ** $p < .001$

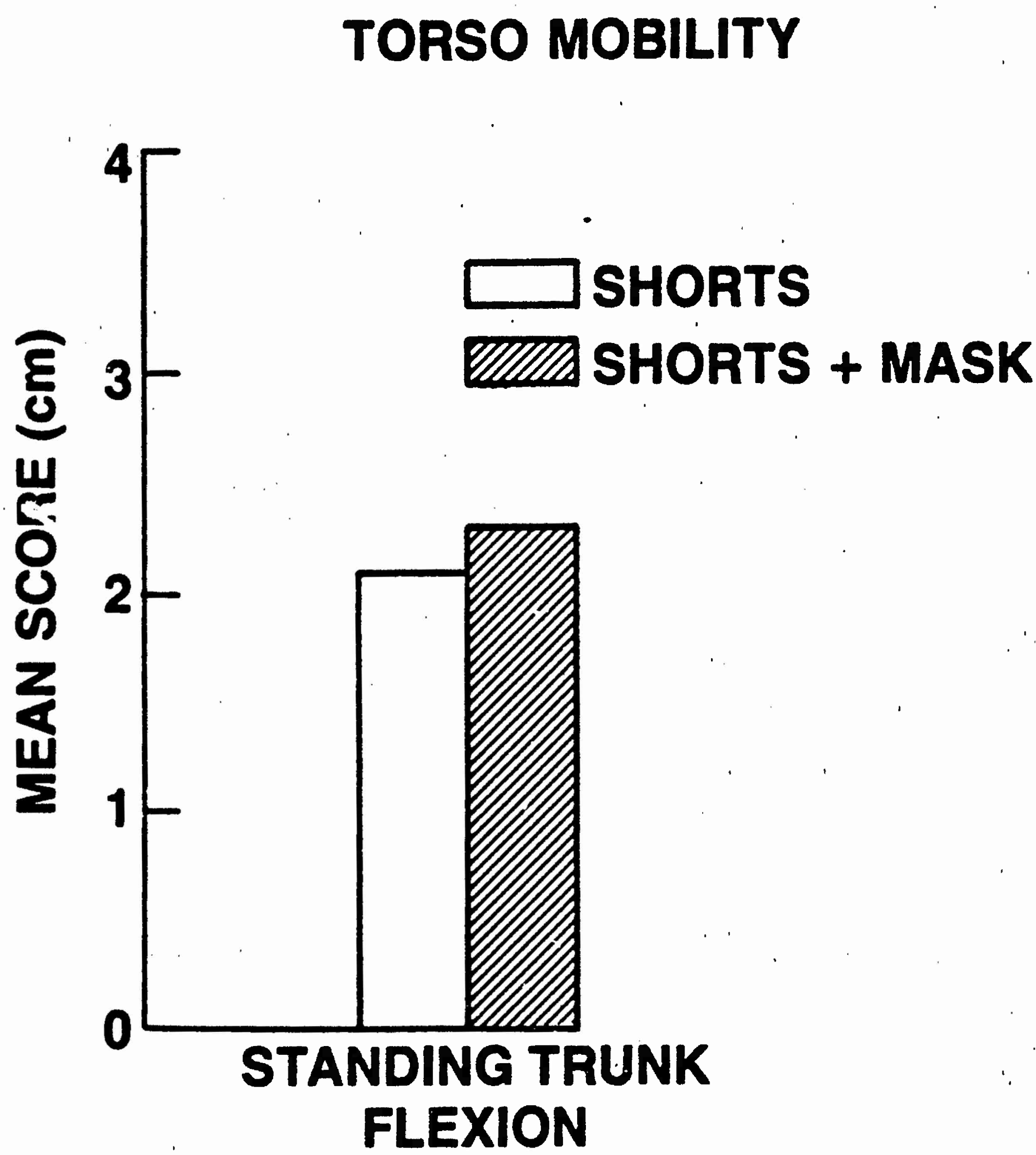

Figure 4. Mean score on Standing Trunk Flexion as a function of shorts and mask.

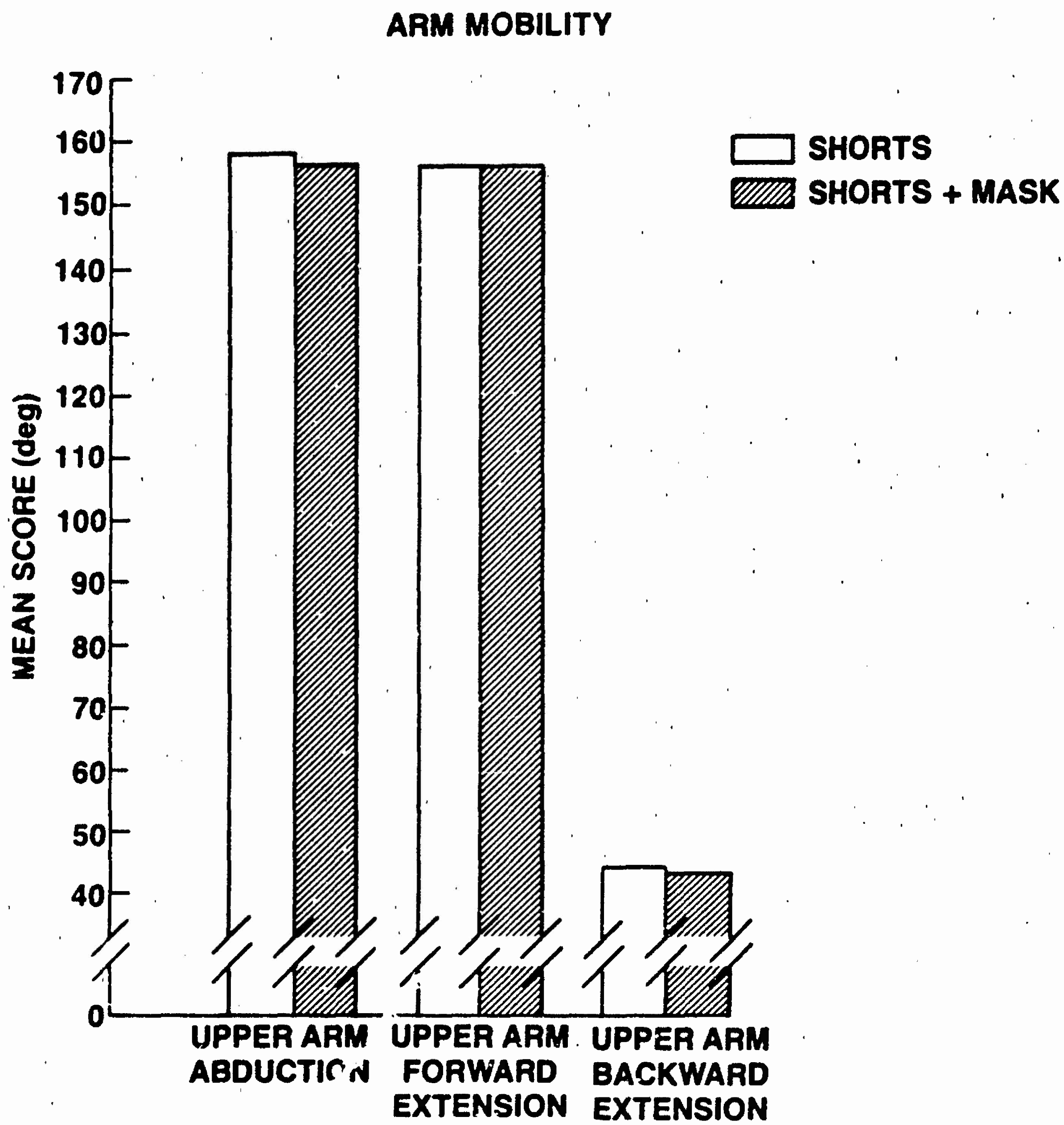

Figure 5. Mean scores on arm mobility tasks as a function of shorts and mask.

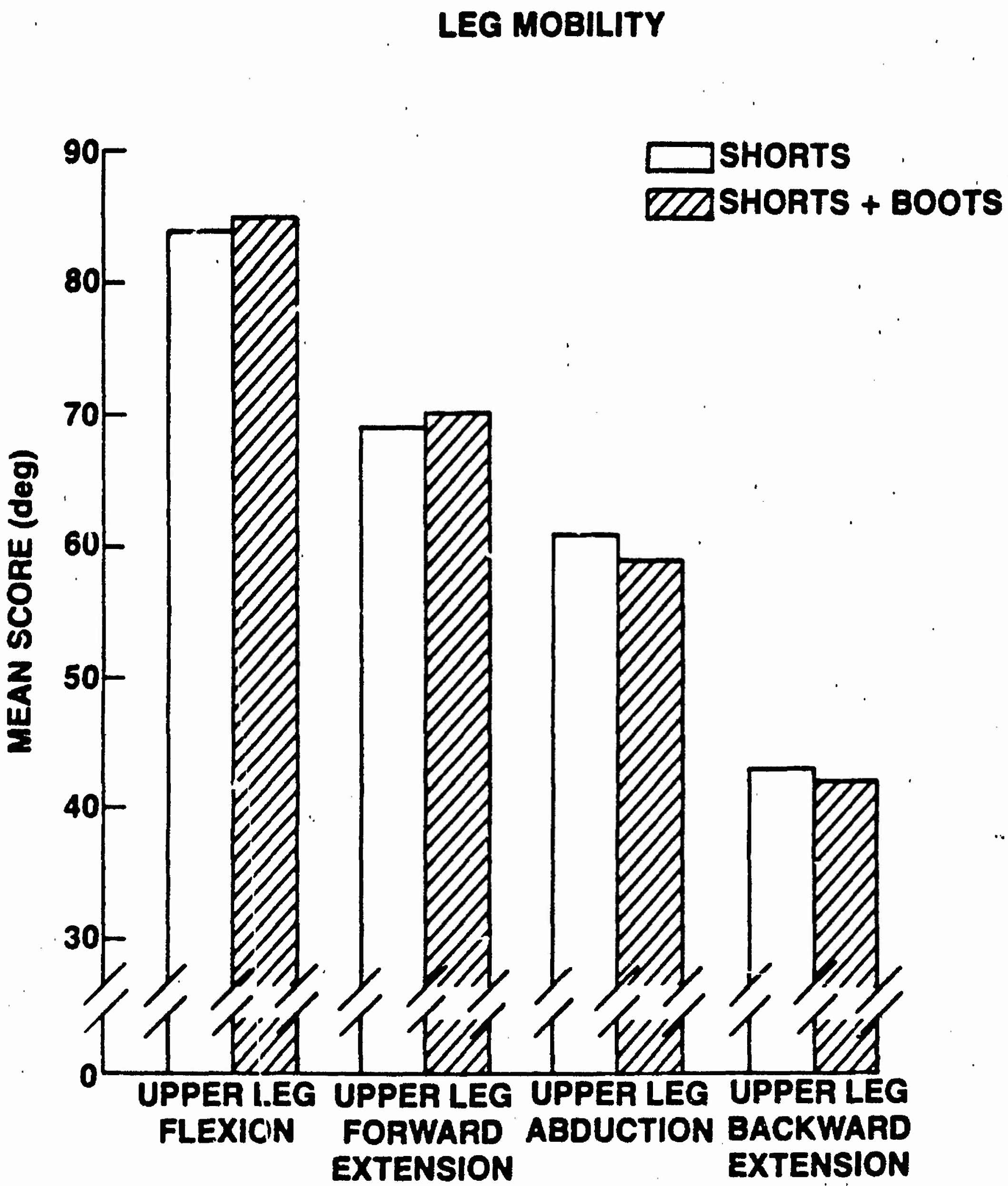

Figure 6. Mean scores on leg mobility tasks as a function of shorts and overboots.

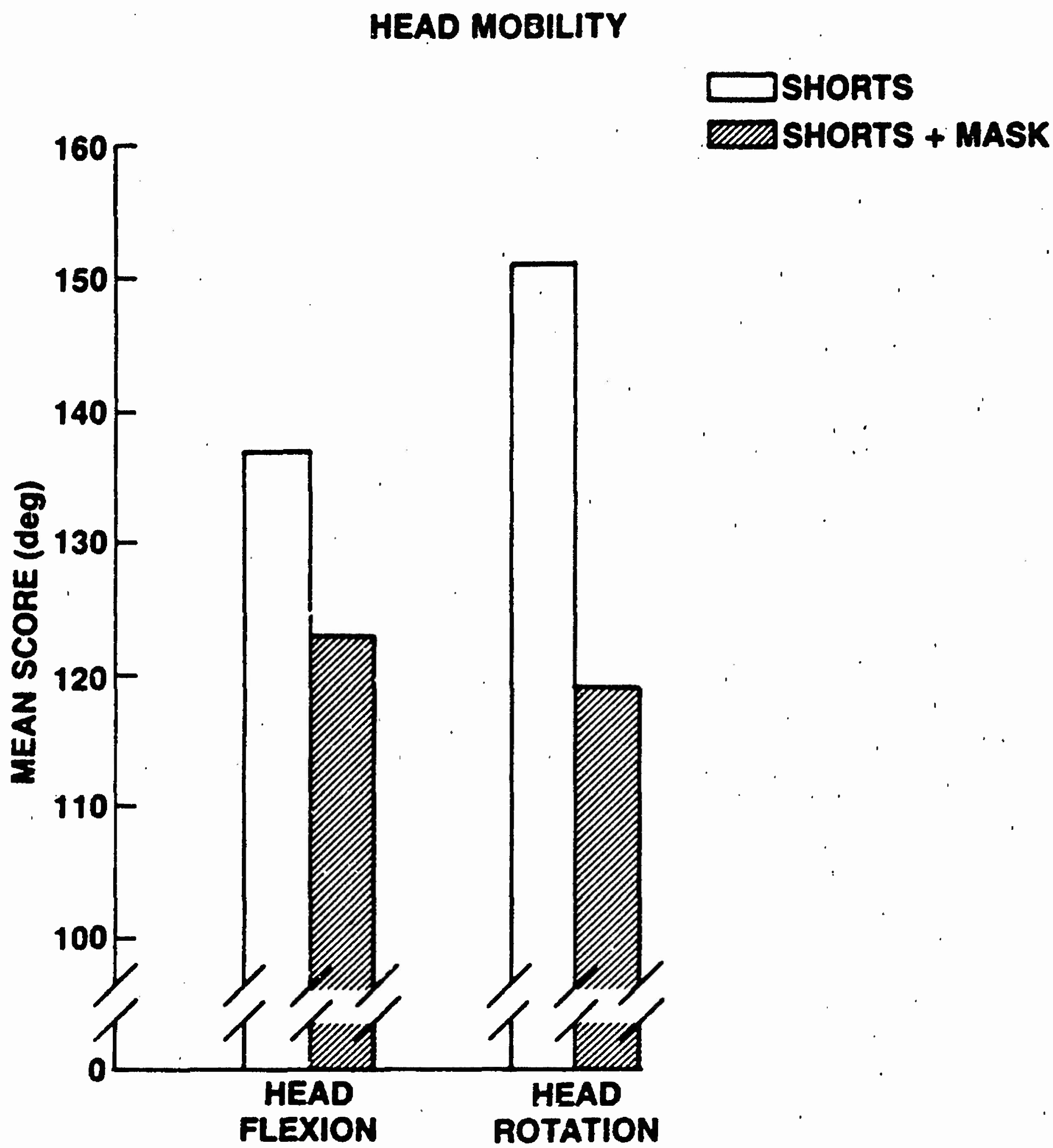

Figure 7. Mean scores on head mobility tasks as a function of shorts and mask.

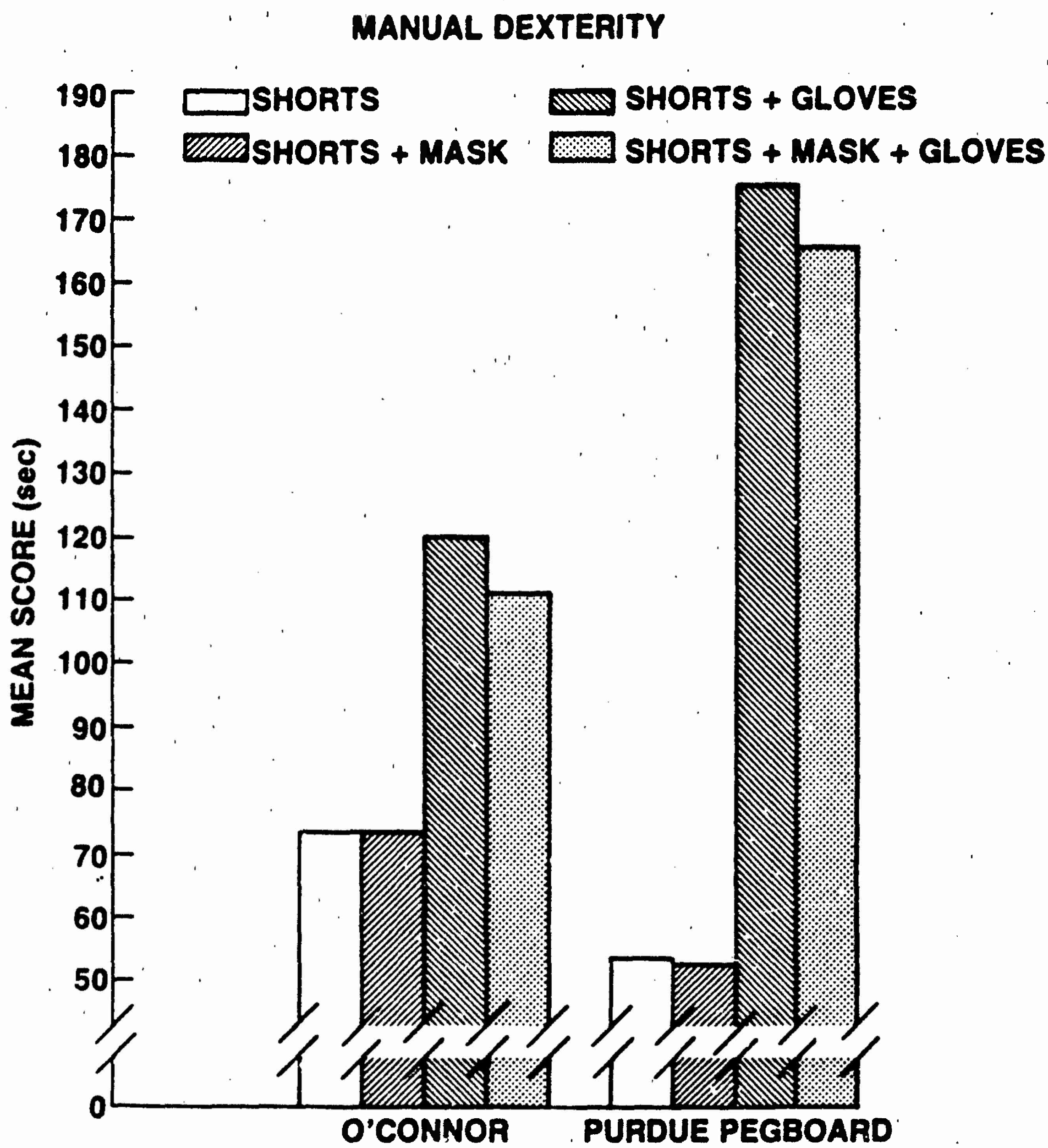

Figure 8 Mean scores on manual dexterity tasks as a function of shorts, mask, and gloves.

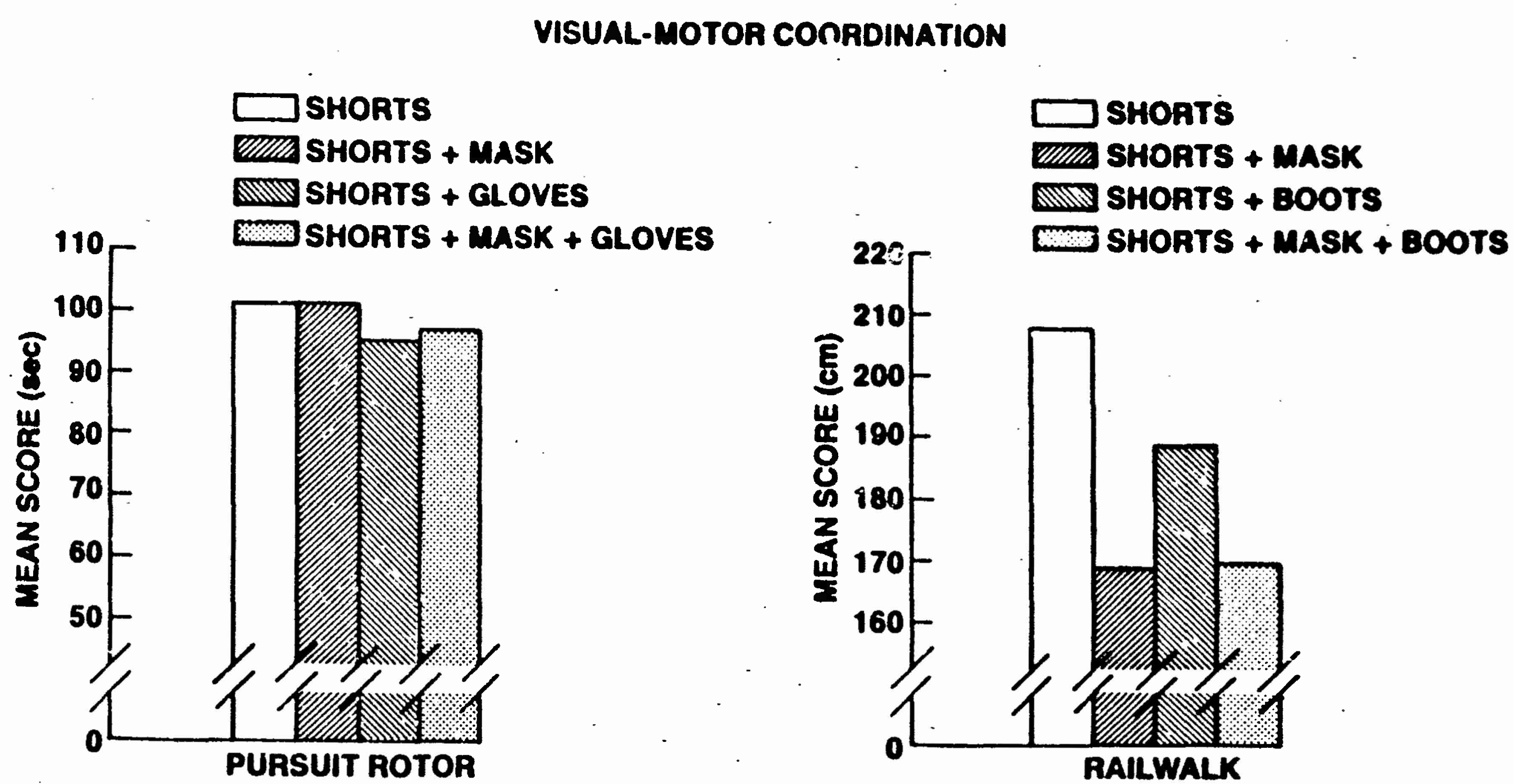

Figure 9. Mean scores on visual-motor coordination tasks as a function of shorts, mask, and overboots or gloves.

Performance on the Pursuit Rotor and the Railwalk was not significantly affected by the clothing items being worn (Table 19). However, scores on the former are slightly better under the two conditions in which the gloves were not used than under the two conditions in which they were (Figure 9). For the Railwalk, performance was better under the two conditions in which the mask was not worn than under the two conditions in which it was (Figure 9).

Median ratings for Section I of the questionnaire are presented in Table 20 and medians for Sections II and III are presented in Tables 21 through 24. The subjects' responses on these sections of the questionnaire were subjected to Wilcoxon tests ($\underline{T}$) if two clothing conditions were involved and $\underline{N}$ was greater than 5 and to Friedman tests ($\underline{X}_r^2$) if at least three clothing conditions were to be compared. The results of these tests are included in the tables.

In Table 20, the median values of 1.0 for the T-shirt and shorts indicate that, in the subjects' opinions, these items did not interfere with their performance on any of the body mobility or the psychomotor tasks. With the exception of the two head movements, the medians for the other clothing conditions under which the mobility tasks were performed are also quite low and similar to the medians for the shorts condition. On Ventral-Dorsal Head Flexion and Head Rotation, the condition in which the mask with hood was worn along with the T-shirt and shorts received relatively high ratings. Based upon the medians, it appears that the subjects considered Head Rotation to be slightly to moderately impaired and Ventral-Dorsal Head Flexion to be moderately to considerably impaired by use of the mask with hood. The results of the Wilcoxon tests performed on these two tasks revealed that the ratings that the subjects assigned when only the T-shirt and shorts were worn differed significantly from the ratings assigned when the mask and hood were also worn (Table 20).

The Friedman tests performed on each of the four psychomotor tasks yielded a significant difference among the rank orderings of the ratings that the subjects assigned to the clothing conditions (Table 20). On the Pursuit Rotor, the ratings given when the mask and hood were the only protective items worn are slightly higher than the ratings given when the only protective items used were the gloves. The highest ratings, with a median value of 3.3, are for the condition in which the mask with hood and the gloves were used together. Similarly, on the Railwalk, the ratings for the mask and hood are slightly higher than those for the overboots and the highest ratings, with a median value of 3.4, are for the condition in which both types of protective items were worn together (Table 20).

The findings for the two manual dexterity tests are similar to each other. On both the O'Connor and the Purdue Assembly Tests, the medians for the condition in which the mask and hood were worn with the T-shirt and shorts approximate the level of slight impairment. The ratings for the condition in which the gloves were worn with the T-shirt and shorts indicate that considerable to extreme impairment was experienced while performing the manual tasks with the handwear. The ratings for the condition in which the mask and hood were used along with the gloves are slightly higher than those for the condition in which the gloves were worn and the headgear was not (Table 20).

TABLE 20. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under Each Condition in Which Shorts and CP Items Were Worn

Task	Shorts	Shorts + Mask	Shorts + Boots	Shorts + Gloves	Shorts + Mask + Boots	Shorts + Mask + Gloves	T^a	(N)	χ_r^{2b}
				Clothing Condition					
				Body Mobility					
1. Standing Trunk Flexion	1.0	1.1	-	-	-	-	-	(2)	-
2. Upper Arm Abduction	1.0	1.0	-	-	-	-	-	(0)	-
3. Upper Arm Forward Extension	1.0	1.0	-	-	-	-	-	(0)	-
4. Upper Arm Backward Extension	1.0	1.0	-	-	-	-	-	(1)	-
5. Upper Leg Flexion	1.0	-	1.1	-	-	-	-	(1)	-
6. Upper Leg Forward Extension	1.0	-	1.3	-	-	-	-	(4)	-
7. Upper Leg Abduction	1.0	-	1.2	-	-	-	-	(3)	-
8. Upper Leg Backward Extension	1.0	-	1.2	-	-	-	-	(2)	-
9. Ventral-Dorsal Head Flexion	1.0	3.6	-	-	-	-	0.0*	(8)	-
10. Head Rotation	1.0	2.4	-	-	-	-	0.0*	(9)	-
				Psychomotor Coordination					
11. Pursuit Rotor	1.0	2.8	-	2.6	-	3.3	-	-	18.65**
12. O'Connor Finger Dexterity	1.0	2.1	-	4.6	-	4.8	-	-	22.01**
13. Purdue Pegboard Assembly	1.0	2.0	-	4.6	-	4.7	-	-	23.24**
14. Railwalk	1.0	3.0	2.8	-	3.4	-	-	-	20.51**

NOTE: Subjects rated the extent to which performance on each task was impaired by the clothing being worn according to the following scale: 1=not at all; 2=slightly; 3=moderately; 4=considerably; 5=extremely.

[a] T was calculated only when $N \geq 6$. [b] $df=3$

*$p<.01$ **$p<.001$

In Sections II and III of the questionnaire, the subjects rated some design characteristics and potential problem areas of the clothing items they were wearing with regard to their importance in interfering with performance of the body mobility and the psychomotor tasks. The ratings assigned to the protective items worn while body mobility testing was being carried out are quite low with the medians rarely exceeding the level of a little importance. The medians associated with psychomotor testing encompass a wider range of values; they are presented in Tables 21 through 24.

The median ratings of the mask's design characteristics and problem areas, which are in Table 21, vary somewhat as a function of the other items that were being worn. For example, the characteristics of mask weight, protruding parts, and lens size and shape received higher ratings for impairing performance when the gloves were used as well than they did when the mask with hood was worn with only the T-shirt and shorts. However, the Friedman tests did not yield any significant differences among the rank orderings of the subjects' ratings of those conditions involving the mask (Table 21).

The mask design characteristics that received the highest ratings, approaching the level of considerable importance in interfering with performance, are weight, protruding parts, and lens size and shape. These ratings were assigned when both the gloves and the mask were worn (Table 21). The median ratings for the potential problem area of blocked vision are relatively high, approaching the level of considerable importance, for all three conditions that involved the mask and the median for the problem of mask pressure is relatively high for the condition in which the gloves were used as well (Table 21).

The median ratings of the design characteristics and potential problems for the hood are presented in Table 22. The medians for the hood indicate that, in general, the subjects had less-negative opinions regarding this item than they did regarding the mask (Table 21). The highest median associated with the hood, a value of 2.3, is for the problem of sweat and the rating indicates that the subjects found this to be of a little importance in interfering with their performance. As was the case with the mask, the ratings given the hood vary somewhat as a function of the other items being worn. For example, the medians for the problems of snagging and bunching are higher under the condition in which the gloves were also used than they are under the condition in which the mask and hood were the only protective items worn. However, the Friedman tests performed on the data for the hood did not yield any results that were significant (Table 22).

The medians for the overboots' design characteristics and potential problem areas are presented in Table 23. The Wilcoxon tests did not reveal any significant differences in subjects' ratings of the two conditions in which overboots were worn. In some instances, the median for the condition in which the overboots were worn with only the T-shirt and shorts is higher than that for the condition is which the mask and hood were also used, whereas, in other instances, the opposite is the case. Among the design characteristics, the highest ratings were given to overboot bulk and protruding parts. The median for the condition in which the overboots were worn with only the T-shirt and shorts and for the condition in which the mask and hood were also worn indicate

TABLE 21. Median Ratings of Mask Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With Shorts

	Clothing Condition			
	Shorts + Mask	Shorts + Mask + Boots	Shorts + Mask + Gloves	X_r^2 [a]
Design Characteristics				
Weight	2.4	2.2	3.6	0.54
Protruding parts	2.9	2.6	3.6	0.14
Lens size	3.1	3.3	3.7	0.14
Lens shape	3.2	3.2	3.7	0.41
Lens clarity	3.2	3.4	3.3	0.54
Problem Areas				
Rubbing	2.4	2.2	2.6	1.23
Heavy	2.7	2.8	3.0	0.14
Hot	2.9	2.2	2.4	0.95
Loose	1.1	1.2	1.1	0.14
Binding	2.0	2.2	2.0	0.32
Tight	1.8	2.2	2.2	0.95
Sweaty	2.1	2.8	3.2	0.86
Pressure	1.8	2.8	3.6	1.14
Digging in	2.3	2.8	3.0	0.14
Pinching	2.0	2.2	2.0	0.04
Slipping	1.2	1.3	1.3	0.41
Blocking vision	3.7	3.8	3.8	0.04
Snagging	2.0	2.2	1.8	0.41
Unbalanced	3.0	2.9	3.0	0.04
Breathing resistance	2.8	2.7	2.4	0.14

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a] $df=2$

TABLE 22. Median Ratings of Hood Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With Shorts

	Clothing Condition			
	Shorts + Mask	Shorts + Mask + Boots	Shorts + Mask + Gloves	X_r^{2a}
Design Characteristics				
Flexibility	1.7	1.6	1.8	0.54
Bulk	2.0	1.8	2.0	0.14
Protruding parts	1.8	1.7	1.4	0.18
Problem Areas				
Rubbing	1.4	1.4	1.3	0.04
Hot	1.8	2.0	2.2	1.14
Loose	1.2	1.3	1.2	0.14
Pressure	1.2	1.4	1.4	1.27
Binding	1.4	1.4	1.6	0.73
Tight	1.3	1.2	1.4	0.95
Sweaty	1.8	2.0	2.3	0.95
Pinching	1.4	1.3	1.3	0.95
Slipping	1.2	1.3	1.3	0.18
Blocking vision	1.3	1.2	1.3	0.04
Snagging	1.4	1.8	2.2	0.54
Pulling	1.4	1.4	1.4	0.95
Bunching up	1.4	1.9	2.1	2.18

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a]df=2

TABLE 23. Median Ratings of Overboot Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Overboots Were Worn With Shorts

	Clothing Condition			
	Shorts + Boots	Shorts + Mask + Boots	$\underline{T}$[a]	($\underline{N}$)
		Design Characteristics		
Flexibility	2.3	2.6	10.5	(6)
Bulk	3.5	3.2	-	(5)
Weight	2.5	2.2	-	(3)
Sole slipperiness	1.9	2.2	3.0	(6)
Protruding parts	3.1	3.1	-	(3)
		Problem Areas		
Bulky	2.8	3.0	-	(4)
Heavy	2.7	2.8	-	(2)
Hot	1.7	2.0	-	(4)
Loose	1.2	1.4	-	(5)
Stiff	1.4	1.3	-	(4)
Sweaty	1.9	2.0	-	(4)
Tight	1.3	1.1	-	(3)
Pressure	1.7	1.1	-	(3)
Pinching	1.2	1.1	-	(4)
Slipping	1.6	2.0	5.0	(6)
Snagging	1.7	1.7	-	(3)
Impaired feel	3.8	3.3	-	(3)

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a]$\underline{T}$ was calculated only when $\underline{N} \geq 6$.

TABLE 24. Median Ratings of Glove Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Gloves Were Worn With Shorts

	Clothing Condition			
	Shorts + Gloves	Shorts + Mask + Gloves	T[a]	(N)
	Design Characteristics			
Thickness	4.3	4.1	-	(3)
Flexibility	3.8	4.1	-	(3)
Finger lengths	3.5	3.9	-	(4)
Slipperiness	3.0	3.3	-	(5)
	Problem Areas			
Bulky	3.0	3.0	9.0	(6)
Rubbing	1.7	1.8	-	(4)
Hot	2.3	2.3	-	(4)
Loose	1.3	1.3	-	(3)
Stiff	2.0	1.8	-	(4)
Sweaty	2.9	2.8	9.0	(6)
Tight	1.9	1.3	16.0	(8)
Pressure	1.4	1.4	-	(3)
Pinching	1.4	1.4	-	(1)
Slipping	2.3	2.1	-	(5)
Snagging	2.2	2.7	-	(5)
Bunching up	1.3	3.0	0.0*	(7)
Impaired feel	4.7	4.7	-	(4)

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a]T was calculated only when $N \geq 6$.

*$p < .02$

that the subjects found these characteristics to be of at least moderate importance in interfering with their performance (Table 23). The problem area with the highest ratings is the impaired feel experienced with the overboots. The medians for both conditions in which the overboots were used indicate that the subjects found this to be a problem of moderate to considerable importance in hindering their performance.

The ratings given the design characteristics of the gloves tend to be more negative than the ratings given the other protective items (Table 24). The medians indicate that the subjects judged the thickness, flexibility, finger lengths, and slipperiness of the gloves to be characteristics of at least moderate importance in impairing their performance. Among the potential problem areas, the highest medians, with a value of 4.7, are for the impaired feel experienced when the gloves were worn with only the T-shirt and shorts, and with the mask and hood as well (Table 24). Of those Wilcoxon tests that were performed on the ratings assigned to the two conditions in which the gloves were worn, only one revealed a significant finding. This is for the problem area of bunching up of the glove material. For the condition in which the mask and hood were not worn, the median for the problem approaches the level of no importance, whereas, for the condition in which the mask and hood, as well as the gloves, were worn, the median indicated a level of moderate impairment (Table 24).

Discussion. The results of this investigation indicate that use of the protective mask and hood, the overboots, and the gloves does not have a deleterious effect on performance of gross movements of the torso, arms, and legs, at least when the torso is minimally encumbered by a T-shirt and shorts. However, it was found that use of the mask with hood does restrict the extent to which the head can be moved compared with the movement possible when no headgear is worn.

In Investigation I, performance on both the Ventral-Dorsal Head Flexion and the Head Rotation tasks was significantly worse in the MOPP IV attire than in the BDU, whereas, in Investigation II, scores on these head movements were unaffected by the type of torso clothing worn. Given the present findings, it appears that use of the mask with hood can limit Head Flexion and Rotation even when the protective overgarment with its stand-up collar is not used.

Compared with the bare head, the extent of ventral-dorsal flexion was reduced by 10% when the mask and hood were used and rotation was reduced by 21%. Based upon the subjects' responses on the questionnaire, the limitations imposed by the mask and hood on Head Flexion would have been expected to be more severe than those imposed on Head Rotation because the median ratings indicated that the former task was moderately to considerably impaired and the latter task slightly to moderately impaired when the mask and hood were worn. However, if the two movements are considered in light of the design features of the mask, the relative performance decrements are not unexpected. The lower portions of the mask's cheek pouches extend well below the level of the wearer's chin. They appeared to contact the chest, limiting the ventral excursion of the head, whereas there are no mask protrusions to limit the dorsal excursion. On the other hand, rotation of the head to both the right and the left was limited by contact of the ventro-lateral surfaces of the mask's cheek pouches with the shoulders. Thus, both extreme positions of the head were affected by the mask

during Head Rotation and, during Head Flexion, the extreme of the ventral excursion was affected, but not the extreme of the dorsal excursion.

During the performance of the body mobility and the psychomotor tasks, the mask was never used without the hood. Therefore, the contribution that the hood made toward limiting head excursions cannot be assessed. However, the mask did contact the body as the head was moved to extreme positions. Thus, the mask, rather than the hood, appeared to be the headgear component responsible for restricted head movements.

In this investigation, as in Investigation I, scores on the three mobility tasks involving arm movements were not significantly affected by the clothing variable. This finding is an indication that the protective hood does not restrict movement of the arm from the shoulder. It is also an indication that the mask does not protrude laterally to the extent that it interferes with raising the arms over the head in the body's frontal or sagittal planes as is required in the execution of the Upper Arm Abduction and the Upper Arm Forward Extension tasks, respectively. In the present investigation, and in Investigation I, there was, as well, no significant effect of the clothing variable on Standing Trunk Flexion. Standing Trunk Flexion requires that the subject bend forward from the waist and extend both arms toward the floor. The hood has the potential for binding the upper arm and shoulder, thus restricting the arm as the subject reaches for the floor. However, in consonance with the results obtained for the three arm flexibility tasks, the analysis of the scores for Standing Trunk Flexion revealed that performance when the mask and hood were worn was not significantly different from performance when only the T-shirt and gym shorts were worn. Performance on the four mobility tasks involving movement of the leg from the hip was also not significantly affected by clothing condition. Therefore, use of the overboots does not appear to hinder simple movements of the leg in the body's frontal or sagittal planes, at least when the body is not encumbered by full length trousers.

The Railwalk, one of the four psychomotor coordination tasks, required leg movements and, like the simple leg flexibility tasks, Railwalk performance was not significantly affected by the clothing conditions included in this investigation. However, the mean scores for the two conditions in which the mask and hood were used were substantially lower, by approximately 18%, than the best mean score, that for the T-shirt and shorts. There were indications in the relative ratings on the questionnaire regarding the extent to which clothing items impaired Railwalk performance that the subjects found the mask to have a more negative impact than the overboots did. Nevertheless, the subjects reported that bulk, protruding parts, and impairment of tactile cues were aspects of the overboots that were of at least moderate importance in interfering with their efforts on the Railwalk.

In Investigation I, the subjects traversed a significantly greater distance along the rail when they were wearing the BDU than when they were wearing the MOPP IV attire. Although a statistically significant effect was not obtained when the Railwalk scores for the shorts, the BDU, and the overgarment were compared in Investigation II, the scores for the overgarment were substantially lower than those for the other two conditions. In the present investigation as well, the lower scores were associated with chemical protective items,

particularly the mask with hood. Thus, there is the possibility that the poorer performance in MOPP IV attire compared with the BDU, which was reported in Investigation I, was a function of the interaction of the overgarment with the protective headwear.

Like the Railwalk, performance on the Pursuit Rotor was not significantly affected by the clothing worn in the present investigation, although a significant difference in scores for the BDU and the MOPP IV attire was obtained in Investigation I. Also, as was the case for the Railwalk, Pursuit Rotor scores did not differ significantly as a function of the torso clothing worn in Investigation II. These findings again raise the possibility that there was some interaction of the overgarment with another protective item, or items, which was reflected in the poorer Pursuit Rotor scores attained in the MOPP IV attire compared with those attained in the BDU.

In this investigation, as in Investigation I, performance levels on the two manual dexterity tasks did vary significantly as a function of the clothing worn. For both the O'Connor and the Purdue Assembly Tests, the best scores were obtained when the T-shirt and shorts were worn alone or with the mask and hood. The means under these two conditions were very similar to each other. The worst performance occurred under the two conditions in which the gloves were used. In one of these conditions, the gloves were the only protective item worn with the T-shirt and shorts and, in the other, the mask and hood were worn as well. Scores for these two conditions did not differ significantly from each other.

The O'Connor Finger Dexterity Test is performed with one hand, whereas the Purdue Pegboard Assembly Test requires two hands. Both tests have been described as involving, primarily, fine finger manipulation of small objects.[42] Thus, it is not unexpected that the mean scores for the two conditions in which gloves were worn were significantly worse than the scores for the two conditions in which the hands were bare. Visual cues, as well, have been found to be important for the successful completion of the O'Connor Test, whereas performance of the Purdue Assembly Test is not as heavily dependent upon the visual component.[43] However, there was no evidence that the two dexterity tasks were differentially affected by use of the mask and hood. Scores on both the O'Connor and the Purdue Assembly Tests were somewhat better, though not significantly so, when the mask and hood were worn along with the gloves than when the gloves were the only protective item being used.

The subjects' responses on the questionnaire, as they pertain to performance of the psychomotor coordination tasks, indicated that certain design characteristics and potential problem areas associated with the mask were of greater importance in interfering with performance when the mask and gloves were worn at the same time than when the gloves were not being used. Also, problems associated with the gloves, such as snagging and bunching up of the material, were rated by the subjects as being of greater importance in interfering with performance when the mask was worn in combination with the gloves than when the gloves were the only protective item used. Thus, it would appear that, from the subjects' perspective, it was more difficult to perform the manual dexterity tasks when outfitted in the mask and the gloves than in the mask alone or in the gloves alone. However, their scores did not reflect these relative levels of

difficulty to the extent that the mean when the mask and hood were worn along with the gloves was slightly superior to the mean when the gloves were worn, but the mask and hood were not.

In the present investigation, it has been determined that the protective mask and hood have a detrimental effect on performance of simple movements of the head. They do not, however, limit simple movements of the torso or the arms. The effects of the mask and hood on performance of the psychomotor tasks, which involve a visual component, also appear to be minimal. Based on the findings from this investigation, the overboots, as well, do not appear to interfere with simple leg movements, or with traversing a rail. On the other hand, the protective gloves do have a deleterious effect on tasks involving manual manipulation of small objects. In the next investigation, Investigation IV, the effects of the protective mask and hood, the overboots, and the gloves on body mobility and psychomotor coordination will again be examined. However, in Investigation IV, the torso was not minimally clothed in a T-shirt and shorts, rather the protective overgarment was used.

Investigation IV. Effects of Wearing CP Items With the CP Overgarment

Clothing conditions and tasks. The clothing conditions included in this investigation were similar to those that comprised Investigation III to the extent that the protective mask with hood, the overboots, and the gloves were tested in various combinations. However, the protective overgarment, worn over the T-shirt and gym shorts, was the basic torso clothing used throughout this investigation, rather than just the T-shirt and shorts alone. Combat boots were used as well, as they had been previously. Also, a total of eight clothing conditions, rather than six, were included in this investigation. The conditions and their designations were:

1. Overgarment (OG).
2. Overgarment, mask with hood (OG + Mask).
3. Overgarment, overboots (OG + Boots).
4. Overgarment, gloves (OG + Gloves).
5. Overgarment, mask with hood, overboots (OG + Mask + Boots).
6. Overgarment, mask with hood, gloves (OG + Mask + Gloves).
7. Overgarment, overboots, gloves (OG + Boots + Gloves).
8. Overgarment, mask with hood, overboots, gloves (OG + Mask + Boots + Gloves).

With a few exceptions, the protective items and the combinations of items that had been used in the performance of each task in Investigation III were also used here. The exceptions pertained to the trunk flexion and the three arm movement tasks. In Investigation III, these tasks had been performed while the mask and hood were being worn, but not while the protective overboots and the gloves were being used. For the present investigation, it was determined that the overboots and the gloves, because they tuck inside the overgarment trouser legs and the coat sleeves, respectively, could interact with the overgarment to affect trunk and arm mobility. Therefore, the one trunk flexion and the three arm mobility tasks were performed under conditions involving the overboots and the gloves, as well as those involving the mask and hood. The conditions tested for each body mobility and each psychomotor coordination task are presented in Table 25.

TABLE 25. Tasks Performed Under Each Clothing Condition Included in Investigation IV

Task	OG	OG+Mask	OG+Boots	OG+Gloves	OG+Mask +Boots	OG+Mask +Gloves	OG+Boots +Gloves	OG+Mask +Boots +Gloves
Body Mobility								
1. Standing Trunk Flexion	o	o	o	o	o	o	o	o
2. Upper Arm Abduction	o	o	o	o	o	o	o	o
3. Upper Arm Forward Extension	o	o	o	o	o	o	o	o
4. Upper Arm Backward Extension	o	o	o	o	o	o	o	o
5. Upper Leg Flexion	o		o					
6. Upper Leg Forward Extension	o		o					
7. Upper Leg Abduction	o		o					
8. Upper Leg Backward Extension	o		o					
9. Ventral-Dorsal Head Flexion	o	o						
10. Head Rotation	o	o						
Psychomotor Coordination								
11. Pursuit Rotor	o	o		o		o		
12. O'Connor Finger Dexterity	o	o		o		o		
13. Purdue Pegboard Assembly	o	o		o		o		
14. Railwalk	o	o	o		o			

Results. The mean scores on each body mobility and each psychomotor task for the various clothing conditions are presented in Table 26 and depicted graphically in Figures 10 through 17. For those tasks on which two clothing conditions were compared, the results of the t tests for small, correlated samples are included in Table 26, whereas, for those tasks on which three or more conditions were compared, the F ratios for the main effects of clothing obtained in the analyses of variance are included.

It can be seen in Table 26 that significant differences in performance as a function of the clothing worn were obtained for two of the body mobility tasks, Ventral-Dorsal Head Flexion and Head Rotation. Performance on these tasks was affected similarly by clothing condition (Figure 15). The extent of each head movement was greater when the overgarment was worn without any additional protective items than when the mask and hood were worn as well (Table 26).

Scores on all psychomotor tasks, except the Railwalk, were also significantly affected by clothing condition. The results of the Newman-Keuls multiple comparison tests performed on the means for the three tasks are presented in Table 26. For the Pursuit Rotor, the Newman-Keuls tests revealed that the best mean time-on-target, that achieved when the overgarment was worn alone, did not differ significantly from the mean when the mask with hood was used or the mean when the gloves were used along with the overgarment. However, the mean time-on-target achieved when the mask with hood and the gloves were worn at the same time was significantly poorer than the means for the other conditions (Table 26).

Mean times to task completion on the O'Connor Finger Dexterity Test were best when the overgarment was worn alone or with the mask and hood. The Newman-Keuls tests did not yield a significant difference between the means for these two conditions. Use of the gloves with the overgarment increased the mean time significantly relative to the means for the two conditions in which the hands were bare. The longest mean time to task completion was obtained when the mask with hood and the gloves were worn with the overgarment. This mean was significantly worse than all others (Table 26).

The best mean scores on the Purdue Pegboard Assembly Test were also achieved under the conditions in which the overgarment was worn alone or with the mask and hood. The scores under these two conditions did not differ significantly from each other. The worst mean scores occurred when the gloves or the mask with hood and the gloves were worn with the overgarment. These means did not differ from each other, but they were significantly different from the means for the overgarment alone and the overgarment plus mask with hood conditions (Table 26).

On the Railwalk, the only psychomotor task for which a significant effect of clothing was not obtained, there were no trends in the data to indicate that use of the mask with hood hindered performance to a greater extent than did use of the overboots, or vice versa (Figure 17).

TABLE 26. Mean Scores for Body Mobility and Psychomotor Tasks Under Each Condition in Which the Overgarment and Other CP Items Were Worn

Task	Clothing Condition[a]								t^{b}	F
				Body Mobility						
1. Standing Trunk Flexion (cm)	7 1.85	5 2.07	1 2.37	2 2.55	4 2.59	3 2.67	8 2.70	6 4.35	-	1.56[c]
2. Upper Arm Abduction (deg.)	8 147.02	5 145.48	3 144.82	2 144.41	7 143.66	6 143.18	1 142.93	4 141.89	-	<1.00[b]
3. Upper Arm Forward Extension (deg.)	1 152.20	5 151.93	8 150.54	4 149.66	3 149.18	6 149.07	7 148.02	2 148.00	-	2.07[d]
4. Upper Arm Backward Extension (deg.)	7 39.70	4 38.88	8 38.52	1 37.68	6 37.55	3 37.00	5 36.61	2 35.48	-	<1.00[d]
5. Upper Leg Flexion (deg.)	3 77.04	1 74.11							0.98	-
6. Upper Leg Forward Extension (deg.)	3 64.64	1 64.36							0.14	-
7. Upper Leg Abduction (deg.)	3 52.61	1 52.07							0.20	-
8. Upper Leg Backward Extension (deg.)	3 40.66	1 40.54							0.05	-
9. Ventral-Dorsal Head Flexion (deg.)	1 139.18	2 114.02							5.15**	-
10. Head Rotation (deg.)	1 147.93	2 100.90							10.64**	-

TABLE 26. Mean Scores for Body Mobility and Psychomotor Tasks Under Each Condition in Which the Overgarment and Other CP Items Were Worn (Cont'd)

Task	Clothing Condition[a]				t^b	F
			Psychomotor Coordination			
11. Pursuit Rotor	1	4	2	6		
(sec)	100.31	97.05	96.38	90.43	-	4.75*[e]
12. O'Connor Finger	1	2	4	6		
Dexterity (sec)	71.58	75.30	105.03	1[illegible]3.17	-	24.27**[e]
13. Purdue Pegboard	2	1	6	4		
Assembly (sec)	52.02	53.[illegible]	179.70	18[illegible].87	-	27.89**[e]
14. Railwalk (cm)	1	5	3	2		
	168.86	167.02	165.70	161.68	-	<1.00[e]

NOTE: Clothing conditions connected by the same line are not significantly different (p>.05).

[a]1=OG; 2=OG+Mask; 3=OG+Boots; 4=OG+Gloves; 5=OG+Mask+Boots; 6=OG+Mask+Gloves; 7=OG+Boots+Gloves; 8=OG+Mask+Boots+Gloves.
[b]df=10
[c]df=7,63
[d]df=7,70
[e]df=3,30
*p<.01
**p<.001

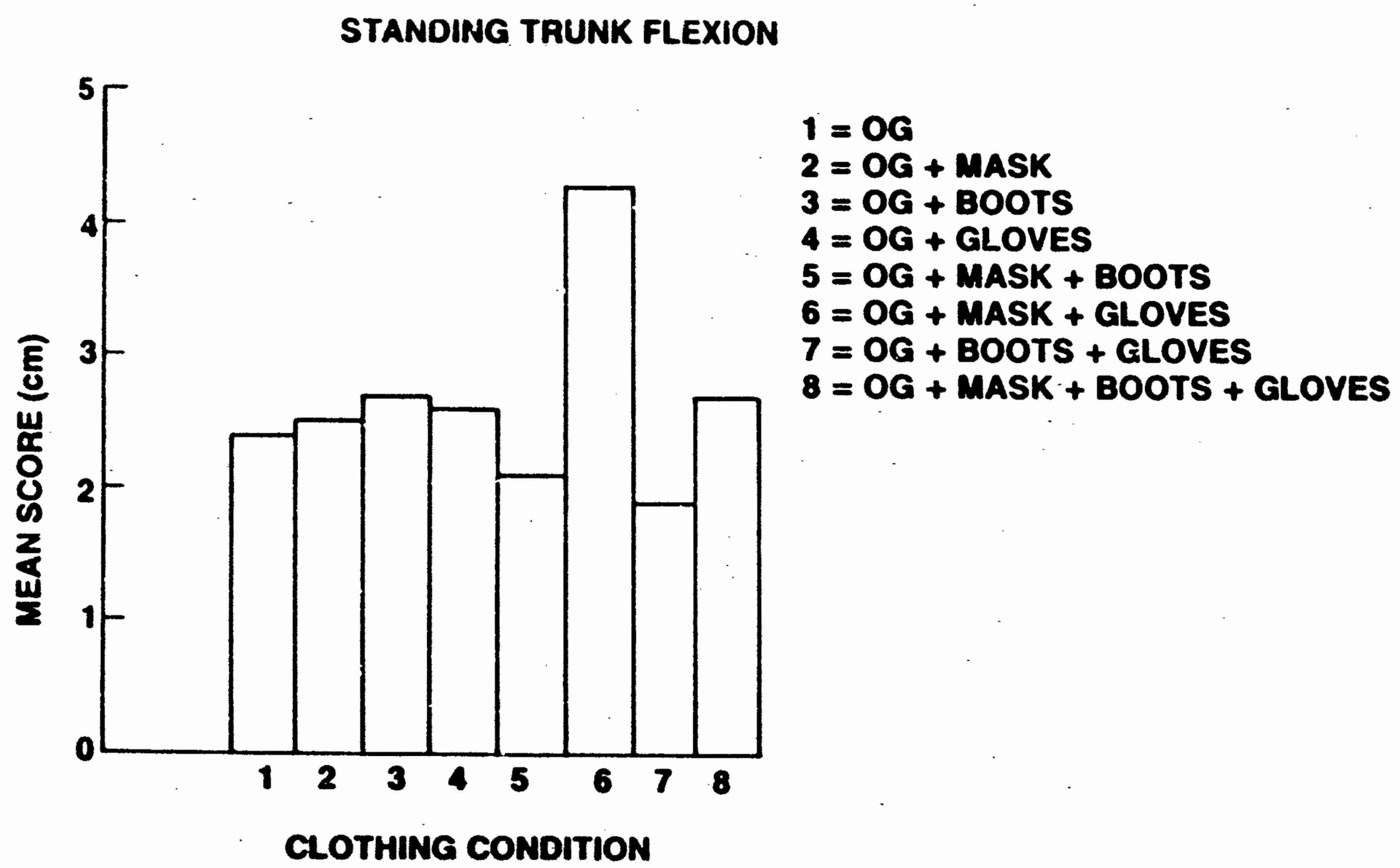

Figure 10. Mean score on Standing Trunk Flexion as a function of overgarment, mask, overboots, and gloves.

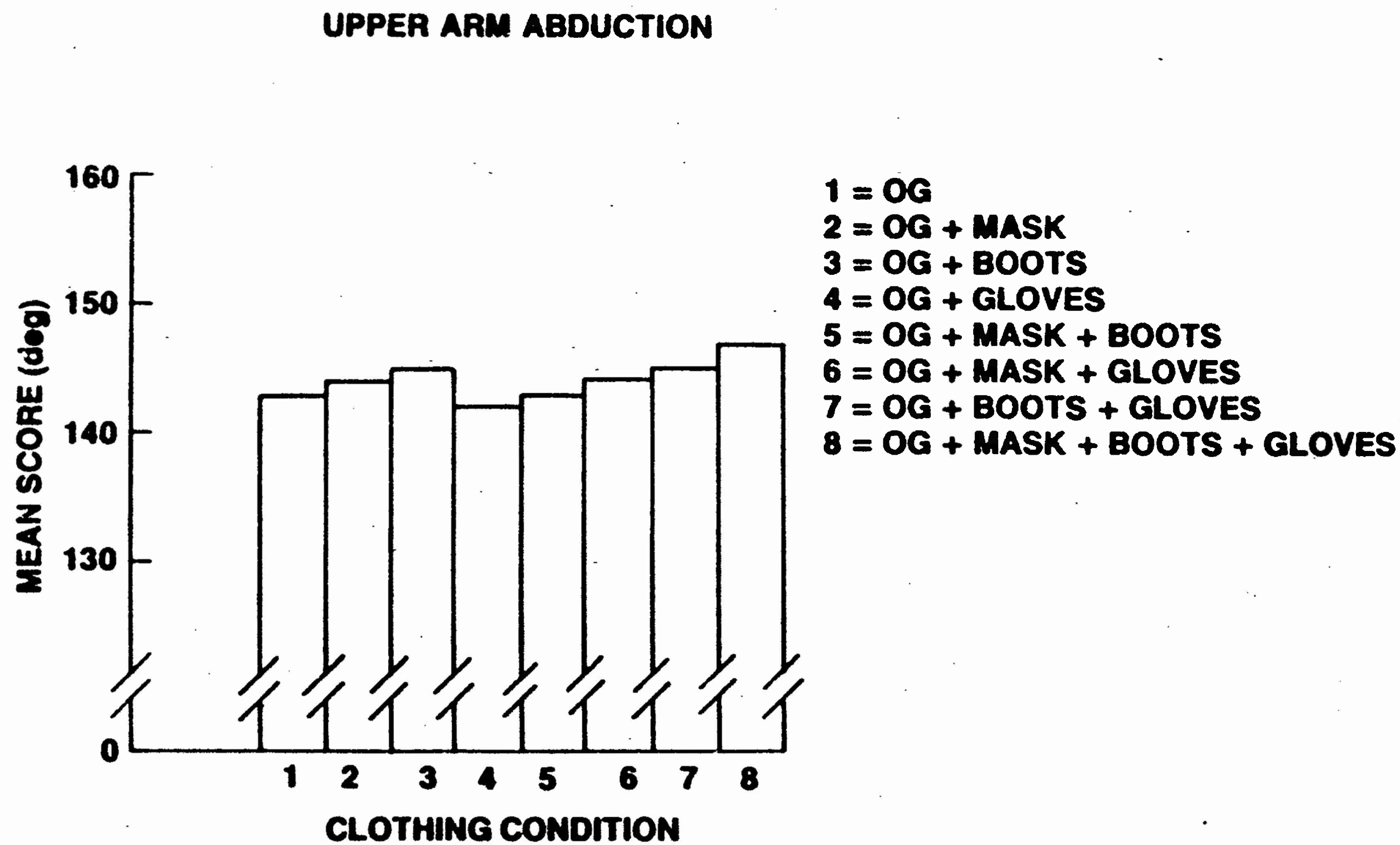

Figure 11. Mean score on Upper Arm Abduction as a function of overgarment, mask, overboots, and gloves.

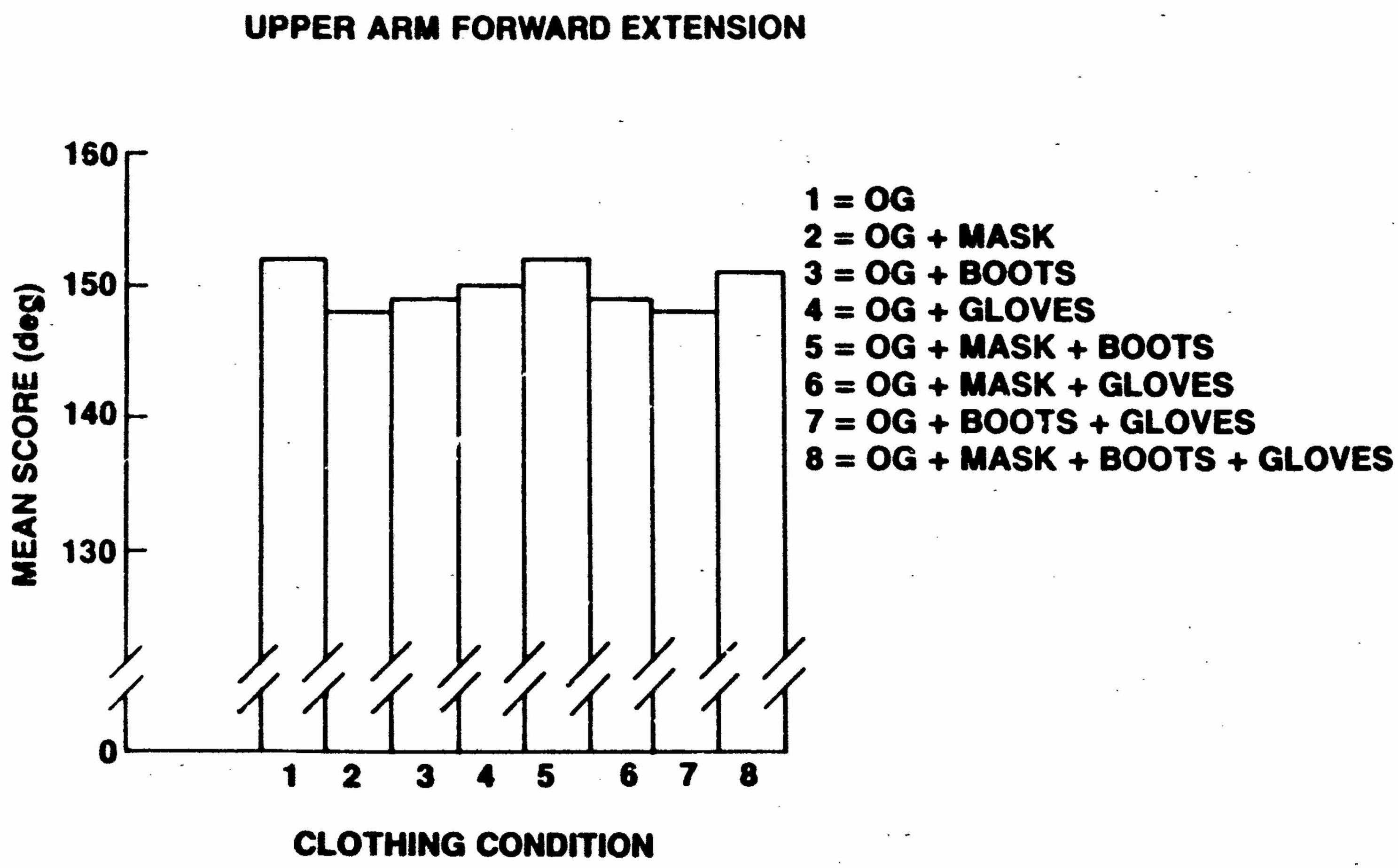

Figure 12. Mean score on Upper Arm Forward Extension as a function of overgarment, mask, overboots, and gloves.

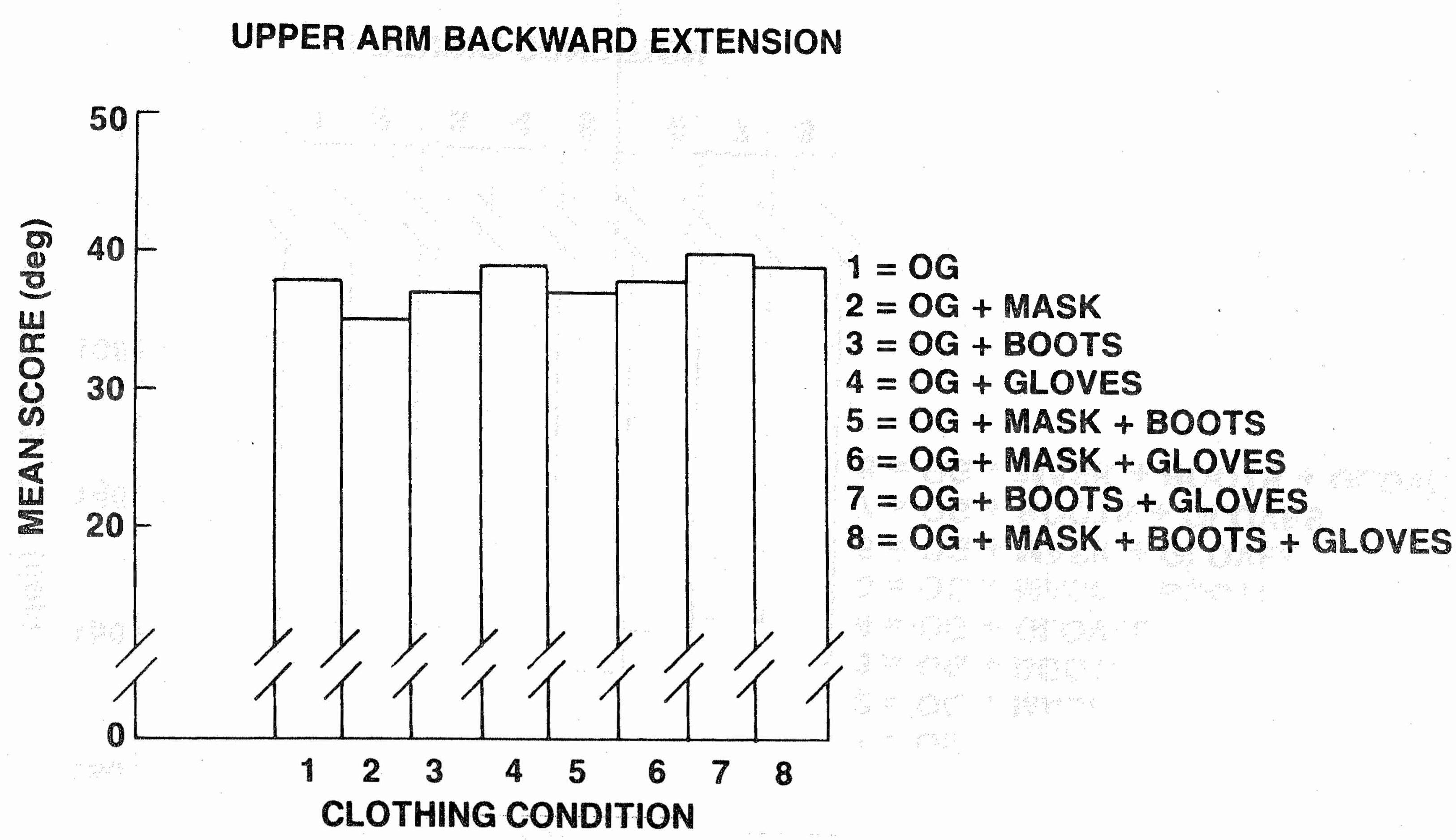

Figure 13. Mean score on Upper Arm Backward Extension as a function of overgarment, mask, overboots, and gloves.

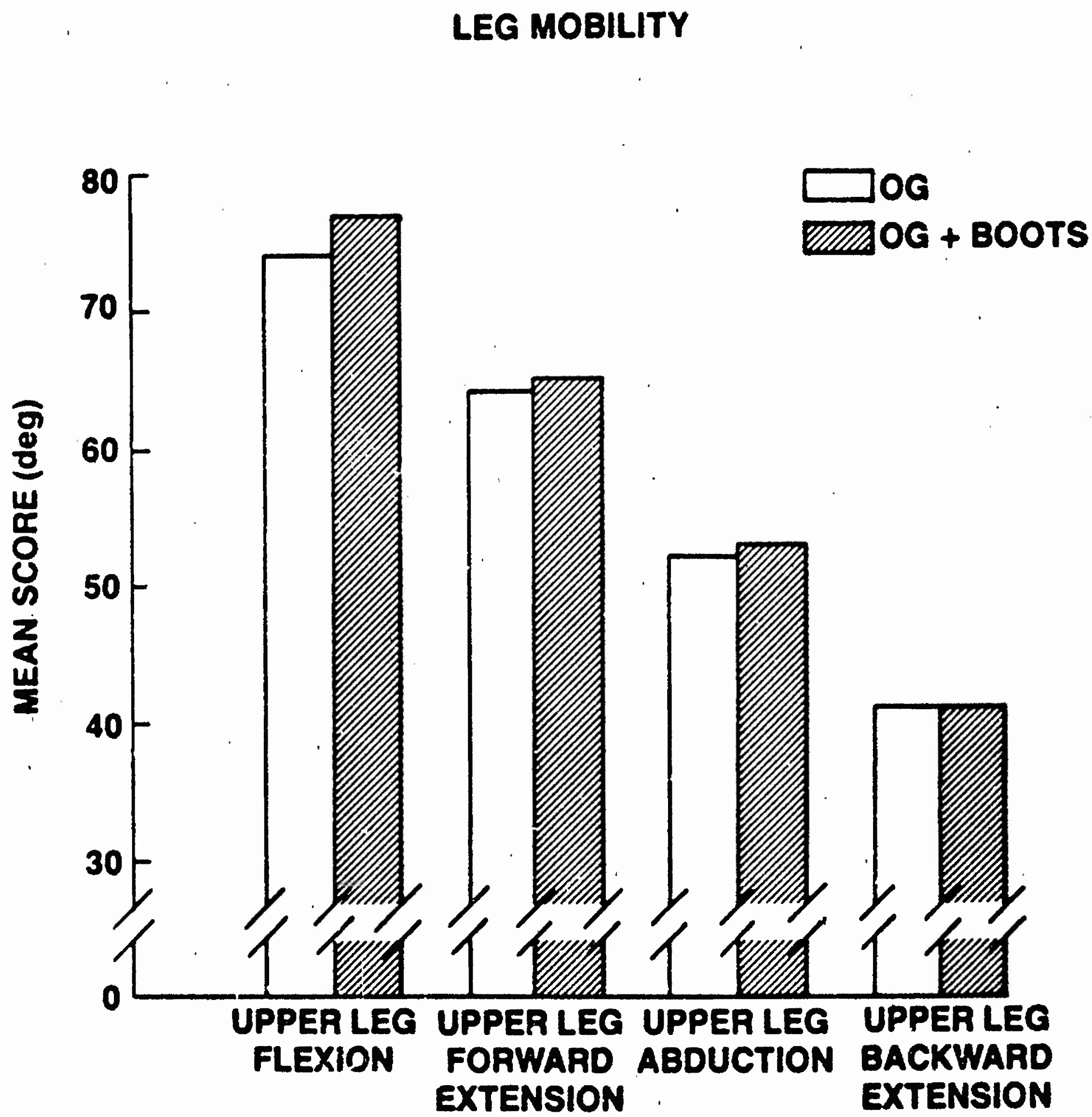

Figure 14. Mean scores on leg mobility tasks as a function of overgarment and overboots.

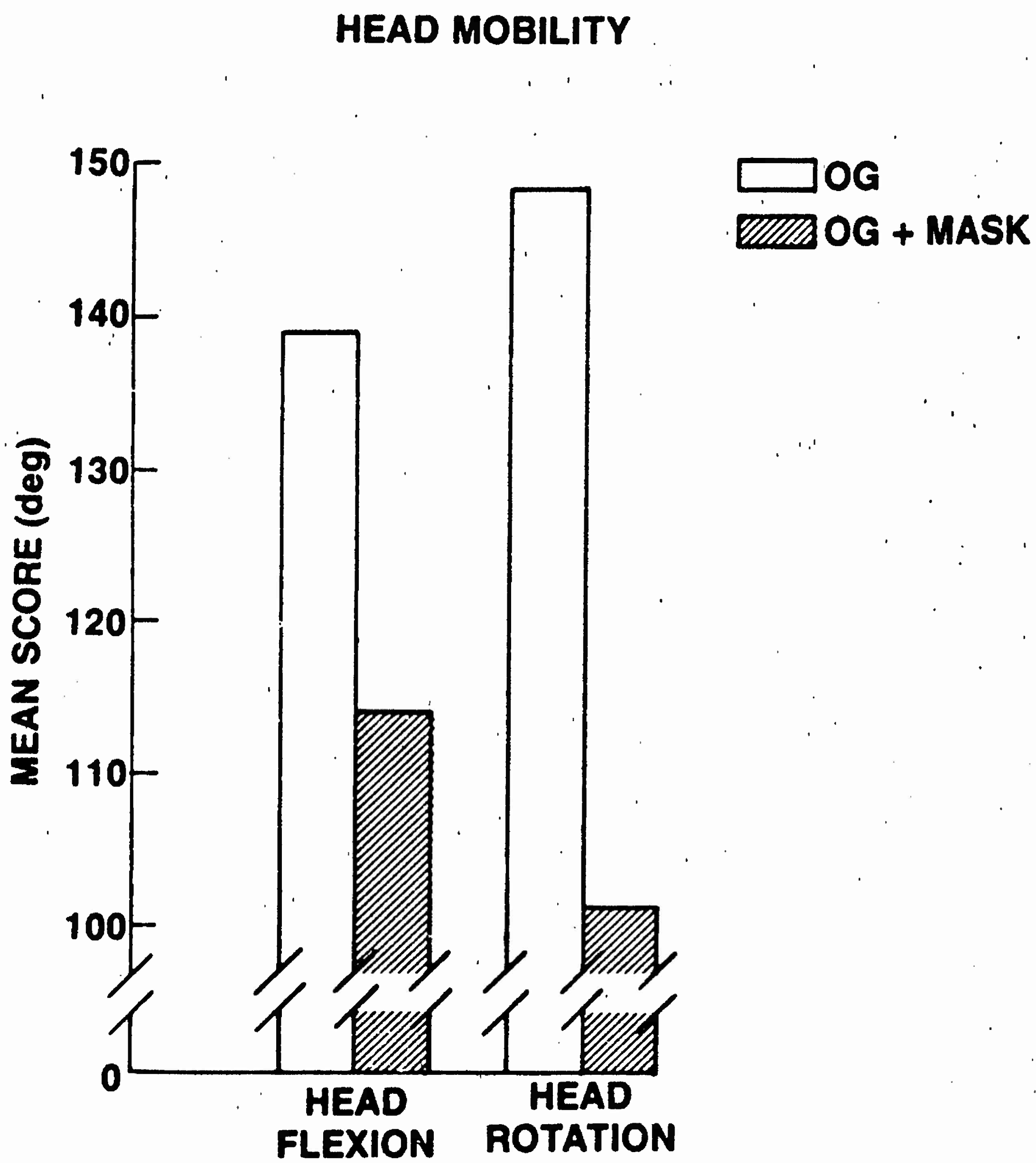

Figure 15. Mean scores on head mobility tasks as a function of overgarment and mask.

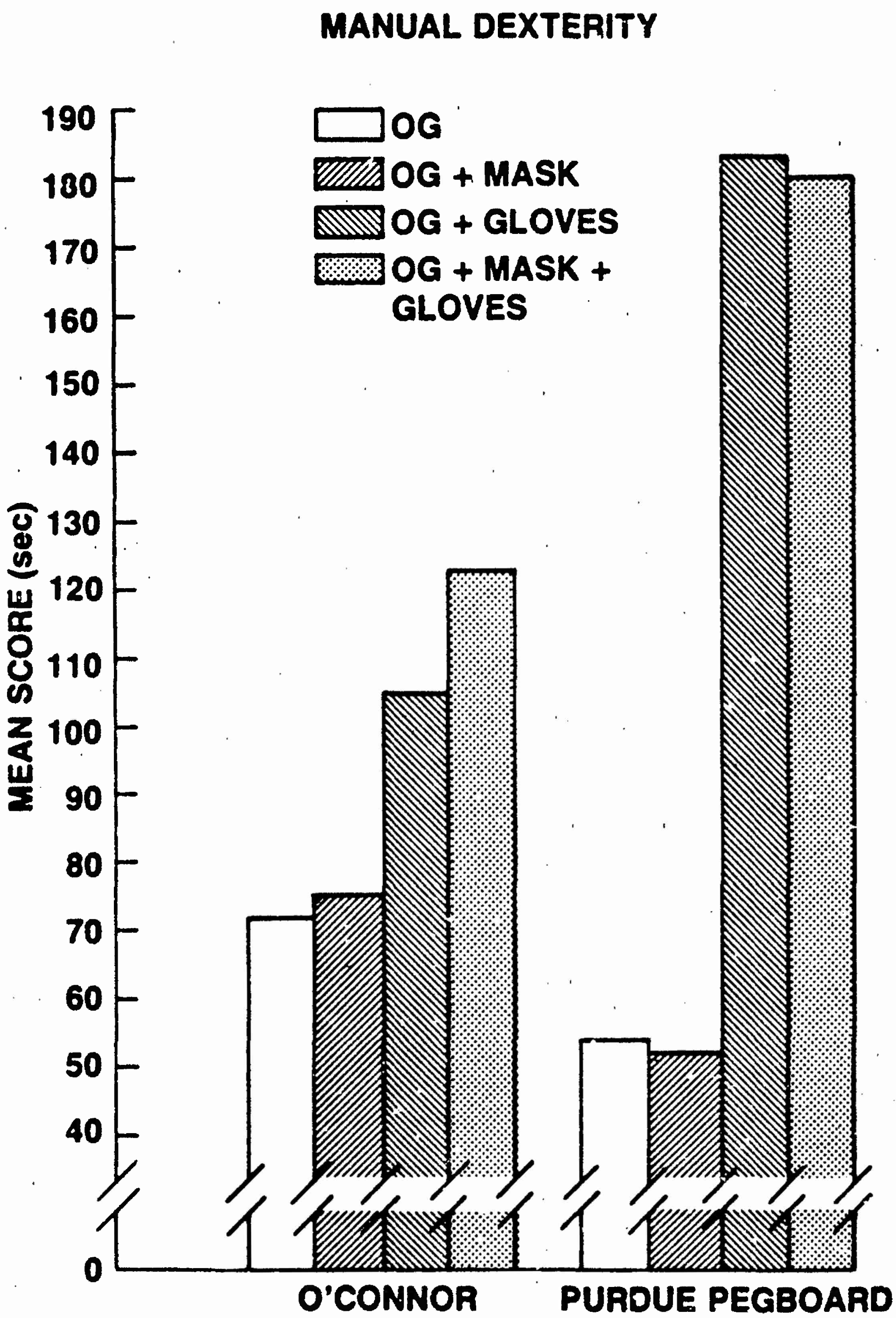

Figure 16. Mean scores on manual dexterity tasks as a function of overgarment, mask, and gloves.

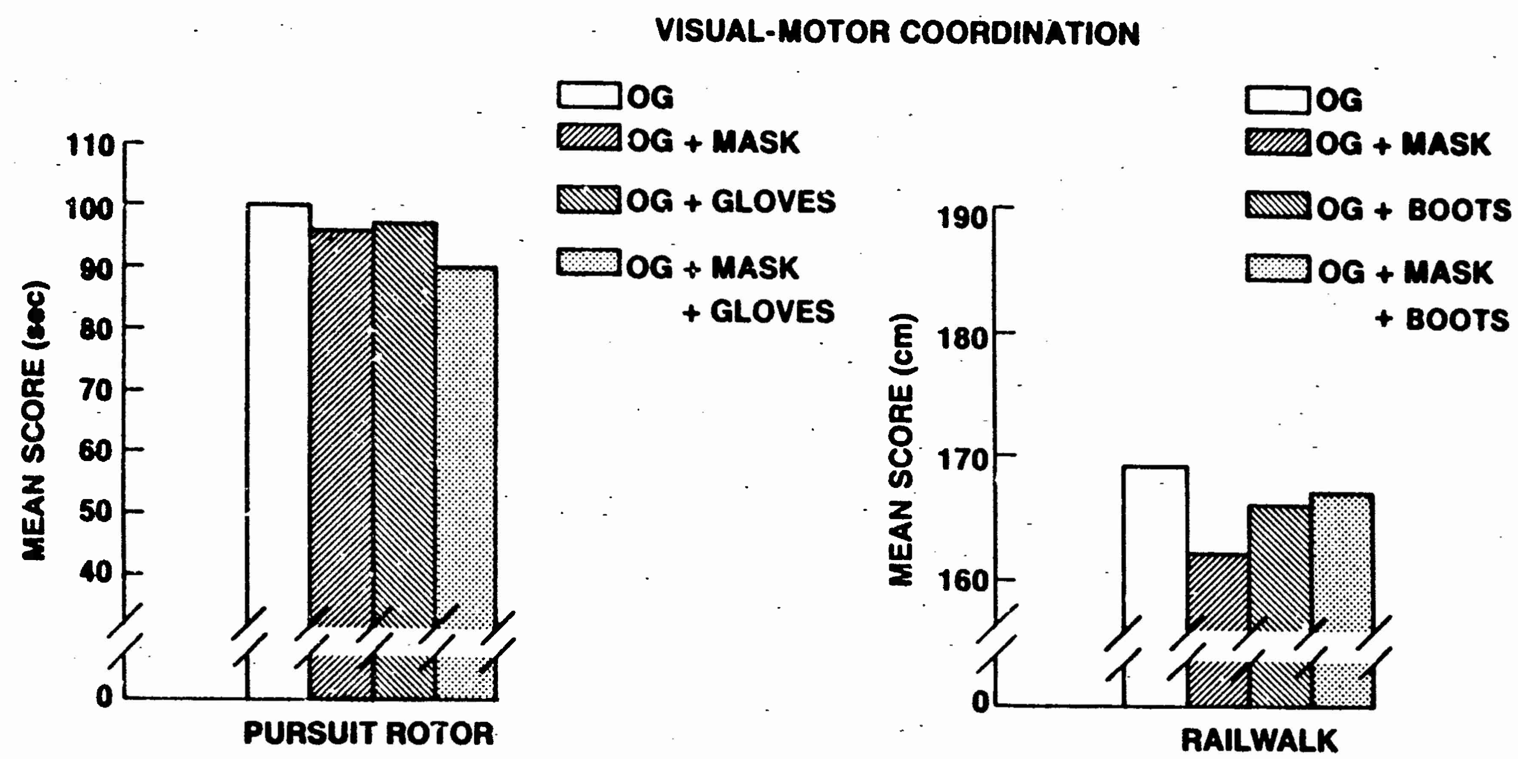

Figure 17. Mean scores on visual-motor coordination tasks as a function of overgarment, mask, and overboots or gloves.

Median ratings for Section I of the questionnaire are presented in Table 27 and medians for Sections II and III are presented in Tables 28 through 31. The subjects' responses on these sections of the questionnaire were subjected to Wilcoxon tests (T) if two clothing conditions were involved and N was greater than 5 and to Friedman tests (X_r^2) if at least three clothing conditions were to be compared. The results of the tests are included in the tables.

In Table 27, the medians for the overgarment condition are relatively low and indicate that, in the subjects' opinions, performance of the body mobility and the psychomotor tasks was at most slightly impaired by use of this item. With the exception of the two head movements, the medians for the other clothing conditions under which the mobility tasks were performed are also relatively low. When the mask and hood were worn along with the overgarment, the subjects rated Ventral-Dorsal Head Flexion as being considerably impaired and Head Rotation as approaching this same level of impairment. The Wilcoxon tests performed on the data for these two head movements revealed that the ratings which the subjects assigned when the mask with hood was used differed significantly from the ratings assigned when the overgarment was worn without any additional items (Table 27). The statistical analyses performed on the ratings for the other body mobility tasks did not yield any significant differences as a function of clothing condition.

On each psychomotor task, the Friedman test revealed a significant difference among the rank orderings of the ratings that the subjects assigned to the clothing conditions. However, there were variations among the tasks in terms of the ratings given (Table 27). For example, the highest medians on the Pursuit Rotor and the Railwalk are slightly above the level of moderate impairment, whereas the highest medians on the O'Connor Finger Dexterity and the Purdue Pegboard Assembly Tests approach the level of extreme impairment.

As can be seen in Table 27, the ratings on the O'Connor and the Purdue Tests indicate that the subjects experienced essentially no impairment in performance when wearing the overgarment without additional protective items and slight to moderate impairment when wearing the mask and hood along with the overgarment. However, for the condition in which the gloves were used with the overgarment, the ratings exceed the level of considerable impairment and the ratings are slightly higher again for the condition in which the gloves and the mask and hood were worn together. The highest ratings on the Pursuit Rotor, which are somewhat above the level of moderate impairment, are also associated with the condition in which the gloves and the mask and hood were worn together (Table 27). However, unlike the dexterity tasks, the ratings on the Pursuit Rotor for the condition in which only the handwear was worn are similar to those given the condition in which only the headgear was used. The subjects' responses indicate that, when either the gloves or the mask and hood were worn separately, impairment of Pursuit Rotor performance approached the moderate level. On the Railwalk, the ratings reflect a level of moderate impairment when the overboots were worn with the overgarment and the ratings are only slightly higher for the two conditions that involved use of the mask and hood (Table 27).

TABLE 27. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under Each Condition in Which the Overgarment and Other CP Items Were Worn

Task	OG	OG+Mask	OG+Boots	OG+Gloves	OG+Mask +Boots	OG+Mask +Gloves	OG+Boots +Gloves	OG+Mask +Boots +Gloves	T^{a}	(N)	χ^2_r
	Clothing Condition										
Body Mobility											
1. Standing Trunk Flexion	1.3	2.0	1.4	1.4	1.5	2.0	1.9	1.2	-	-	6.65[b]
2. Upper Arm Abduction	1.3	2.4	1.8	1.9	2.0	2.3	1.9	2.0	-	-	7.77[b]
3. Upper Arm Forward Extension	1.8	2.0	1.9	1.8	1.9	2.1	1.8	1.8	-	-	2.48[b]
4. Upper Arm Backward Extension	1.3	2.3	1.6	2.0	1.7	2.3	2.1	2.4	-	-	7.22[b]
5. Upper Leg Flexion	1.7	-	1.9	-	-	-	-	-	-	(4)	-
6. Upper Leg Forward Extension	1.7	-	1.8	-	-	-	-	-	-	(4)	-
7. Upper Leg Abduction	1.7	-	1.9	-	-	-	-	-	10.5	(6)	-
8. Upper Leg Backward Extension	1.6	-	2.0	-	-	-	-	-	-	(4)	-
9. Ventral-Dorsal Head Flexion	1.2	4.0	-	-	-	-	-	-	1.0*	(9)	-
10. Head Rotation	1.2	3.8	-	-	-	-	-	-	0.0*	(8)	-
Psychomotor Coordination											
11. Pursuit Rotor	1.3	2.8	-	2.8	-	3.4	-	-	-	-	14.32*[c]
12. O'Connor Finger Dexterity	1.1	2.4	-	4.6	-	4.7	-	-	-	-	25.94**[c]
13. Purdue Pegboard Assembly	1.0	2.2	-	4.2	-	4.7	-	-	-	-	24.79**[c]
14. Railwalk	1.9	3.2	3.0	-	3.2	-	-	-	-	-	11.81*[c]

NOTE: Subjects rated the extent to which performance on each task was impaired by the clothing being worn according to the following scale: 1=not at all; 2=slightly; 3=moderately; 4=considerably; 5=extremely.

[a] T was calculated only when $N \geq 6$. [b] $df=7$. [c] $df=3$.

* $p<.01$ ** $p<.001$

In Sections II and III of the questionnaire, where the subjects rated some design characteristics and potential problem areas of the clothing, the ratings assigned to the items worn while body mobility testing was being carried out are low, with the medians rarely exceeding the level of a little importance. The medians associated with psychomotor testing encompass a wider range of values; they are presented in Tables 28 through 31.

The median ratings of the mask's design characteristics and problem areas, which are in Table 28, vary somewhat as a function of the other items being worn. For example, the characteristics of mask weight and protruding parts received higher ratings for interfering with psychomotor performance when the gloves were used as well than they did when the mask with hood alone was worn with the overgarment. However, the Friedman tests did not yield any significant differences among the rank orderings of the subjects' ratings of those conditions involving the mask (Table 28).

The mask design characteristic that received the highest ratings, approaching the level of considerable importance in interfering with performance, is protruding parts. These ratings were assigned when both the mask and the gloves were worn (Table 28). The median ratings for the potential problem area of blocked vision are relatively high, exceeding the level of moderate importance, for all three conditions that involved the mask and the medians for the potential problems of pressure and heat are relatively high for the condition in which the gloves were used as well (Table 28).

The median ratings of the design characteristics and potential problems for the hood, which are presented in Table 29, are generally lower than those for the mask (Table 28). The highest median associated with the hood, a value of 2.3, is for the problem of sweat and the rating indicates that the subjects found this to be of a little importance in interfering with their performance. As was the case with the mask, the ratings given the hood vary somewhat as a function of the other items being worn. For example, the medians for the problems of sweating and bunching are higher under the condition in which the gloves were used and under the condition in which the overboots were used than they are under the condition in which only the mask and hood were worn with the overgarment. However, the Friedman tests performed on the ratings given the hood did not yield any significant results (Table 29).

The medians for the overboots' design characteristics and potential problem areas are presented in Table 30. The Wilcoxon test, which was carried out on the data for the design characteristic of flexibility, did not reveal a significant difference in subjects' ratings of the two conditions in which overboots were worn. In some instances, the median for the condition in which only the overboots were worn with the overgarment is higher than that for the condition in which the mask and hood were also used, whereas, in other instances, the opposite is the case. Among the design characteristics, relatively high ratings were given to overboot bulk. The medians for both conditions in which the overboots were worn indicate that the subjects found this characteristic to be of at least moderate importance in interfering with performance. The median rating for the design characteristic of protruding parts also exceeds the level of moderate impairment under the condition in which

TABLE 28. Median Ratings of Mask Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With the Overgarment

	Clothing Condition			
	OG+Mask	OG+Mask +Boots	OG+Mask +Gloves	X_r^{2a}
Design Characteristics				
Weight	2.1	1.3	3.0	1.95
Protruding parts	2.7	2.0	3.6	1.77
Lens size	2.8	2.8	3.2	1.77
Lens shape	2.8	2.2	3.2	0.95
Lens clarity	2.8	2.7	3.1	2.77
Problem Areas				
Rubbing	2.1	1.8	3.0	0.54
Heavy	2.1	2.8	3.0	1.27
Hot	2.3	2.3	3.3	6.73
Loose	1.0	1.2	1.1	0.41
Binding	2.0	2.2	2.9	1.95
Tight	2.2	1.8	2.8	2.23
Sweaty	2.3	2.7	3.0	1.41
Pressure	2.7	2.2	3.8	2.86
Digging in	1.8	2.0	2.7	0.95
Pinching	1.6	1.7	2.2	3.45
Slipping	1.3	1.3	1.3	0.95
Blocking vision	3.0	3.4	3.4	1.95
Snagging	1.8	1.7	2.6	0.59
Unbalanced	2.2	2.8	2.8	0.41
Breathing resistance	1.8	2.1	2.9	0.54

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no· 2=little; 3=moderate; 4=considerable; 5=extreme.

[a]df=2

TABLE 29. Median Ratings of Hood Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which the Mask and Hood Were Worn With the Overgarment

	Clothing Condition			
	OG+Mask	OG+Mask +Boots	OG+Mask +Gloves	χ_r^{2a}
		Design Characteristics		
Flexibility	1.2	1.2	1.4	0.14
Bulk	1.2	1.2	1.8	0.95
Protruding parts	1.6	1.3	2.0	1.27
		Problem Areas		
Rubbing	1.2	1.3	1.4	0.41
Hot	1.8	1.8	2.0	0.41
Loose	1.0	1.2	1.2	0.59
Pressure	1.2	1.3	1.2	0.14
Binding	1.3	1.4	1.4	0.59
Tight	1.3	1.2	1.2	0.18
Sweaty	1.3	2.0	2.3	2.91
Pinching	1.3	1.4	1.4	0.95
Slipping	1.3	1.1	1.2	0.95
Blocking vision	1.3	1.2	1.8	1.64
Snagging	1.4	1.4	1.7	0.14
Pulling	1.3	1.3	1.4	0.32
Bunching up	1.4	1.7	2.0	0.32

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a] df=2

TABLE 30. Median Ratings of Overboot Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Overboots Were Worn With the Overgarment

	Clothing Condition			
	OG+Boots	OG+Mask +Boots	T^a	(N)
Design Characteristics				
Flexibility	2.3	2.3	9.0	(6)
Bulk	3.2	3.0	-	(5)
Weight	2.2	2.1	-	(4)
Sole slipperiness	2.0	1.8	-	(4)
Protruding parts	3.2	2.7	-	(3)
Problem Areas				
Bulky	3.1	3.2	-	(5)
Heavy	2.4	2.8	-	(5)
Hot	1.8	1.8	-	(4)
Loose	1.4	1.3	-	(4)
Stiff	1.4	1.7	-	(2)
Sweaty	1.9	2.2	-	(3)
Tight	1.3	1.3	-	(4)
Pressure	1.4	1.7	-	(5)
Pinching	1.3	1.3	-	(2)
Slipping	2.6	1.6	-	(4)
Snagging	2.0	1.7	-	(2)
Impaired feel	4.0	4.3	-	(5)

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a]T was calculated only when N≥6.

TABLE 31. Median Ratings of Glove Design Characteristics and Problem Areas for Psychomotor Tasks Under Each Condition in Which Gloves Were Worn With the Overgarment

	Clothing Condition			
	OG+Gloves	OG+Mask +Gloves	T[a]	(N)
	Design Characteristics			
Thickness	4.4	4.3	-	(3)
Flexibility	3.4	4.2	3.5	(6)
Finger lengths	2.9	3.8	-	(4)
Slipperiness	3.3	3.0	6.0	(6)
	Problem Areas			
Bulky	3.0	3.6	8.0	(6)
Rubbing	2.0	1.7	-	(5)
Hot	2.6	3.2	-	(5)
Loose	1.4	1.4	-	(2)
Stiff	2.3	2.2	-	(5)
Sweaty	2.9	3.6	8.0	(8)
Tight	2.1	2.4	-	(5)
Pressure	2.0	2.0	-	(5)
Pinching	2.0	1.8	-	(5)
Slipping	2.2	2.2	-	(2)
Snagging	2.0	2.2	-	(3)
Bunching up	2.0	2.7	-	(5)
Impaired feel	4.7	4.6	-	(2)

NOTE: Subjects rated the importance of each design characteristic and problem area in interfering with performance according to the following scale: 1=no; 2=little; 3=moderate; 4=considerable; 5=extreme.

[a] T was calculated only when N≥6.

the overboots, but not the mask and hood, were worn (Table 30). The problem area with the highest ratings is the impaired feel experienced with the overboots. The medians for both conditions in which the overboots were used indicate that the subjects found this to be a problem of considerable importance in hindering their performance. Overboot bulk was also cited as a problem of at least moderate importance (Table 30).

The median ratings given the design characteristics and potential problem areas associated with the protective gloves are presented in Table 31. The Wilcoxon tests did not yield significant differences in the subjects' ratings of the two conditions in which the gloves were worn. However, the medians for a number of characteristics and problem areas indicate that the subjects judged their performance to be impaired to a greater extent by the gloves when the mask and hood were worn as well than when the headgear was not used (Table 31). For example, the median rating for the characteristic of finger lengths approaches the level of moderate importance under the condition in which only the gloves were worn with the overgarment, whereas this characteristic has a median approaching the level of considerable importance under the condition in which the mask and hood were also used. The characteristic of glove thickness has relatively high ratings under both conditions that involved handwear. The medians indicate that the subjects found the thickness to be a characteristic of more than considerable importance in hindering their performance. Among the potential problem areas, the highest ratings, with medians exceeding the level of considerable importance, are for the impairment in feel experienced when the gloves were worn, regardless of whether or not the mask and hood were used (Table 31).

Discussion. In Investigation III, it was found that use of the protective mask and hood, the overboots, and the gloves did not have a deleterious effect on performance of tasks involving simple movements of the torso, the arms, and the legs when the torso was clothed in a T-shirt and gym shorts. The results of the present investigation indicate that these items of protective headgear, footwear, and handwear do not have a negative impact on torso, arm, and leg movements even when the torso clothing includes the overgarment coat and trousers. However, as was found in the previous investigations that included the mask with hood, use of the protective headgear does restrict the extent to which the head can be moved compared with that possible when the head is bare.

The decrements in Head Flexion and Rotation associated with the protective mask and hood were substantial in the present investigation. Compared with scores when the overgarment was worn without any other protective items, the extent of ventral-dorsal flexion was reduced by 18% when the mask and hood were also worn and rotation was reduced by an even greater amount, 32%. The subjects themselves indicated in their responses on the questionnaire that they were aware of the limitations that the mask and hood imposed on their head movements. They rated their performance of the two movements as being essentially unimpaired when the head was bare and considerably impaired when the mask and hood were used.

As was discussed in the context of the findings from Investigation III, the fact that there was a greater percentage difference between scores for the bare

head and for the mask with hood conditions on the Head Rotation task than on the Head Flexion task appears to be related to the mask's design. The lower portion of the mask's cheek pouches limited the ventral excursion of the head, but there are no mask protrusions to limit the dorsal excursion. On the other hand, rotation of the head to both the left and the right was limited by contact of the ventro-lateral surfaces of the mask's cheek pouches with the shoulders. Thus, both extreme positions of the head were affected by the mask during Head Rotation and, during Head Flexion, the extreme of the ventral excursion was affected, but not the extreme of the dorsal excursion.

The mask was never used without the hood when the body mobility and the psychomotor tasks were being performed. Therefore, the contribution that the hood made toward restricting Head Flexion and Head Rotation cannot be assessed. However, as was also found in Investigation III, the mask did contact the body as the head was moved to extreme positions. Thus, the mask, rather than the hood, again appeared to be the component that limited Head Flexion and Head Rotation.

Performance on three of the four psychomotor coordination tasks was significantly affected by the protective items being worn. The Railwalk was the one psychomotor task for which a statistically significant effect was not obtained. The best scores on the Railwalk were achieved when the overgarment was worn alone and the addition of protective headgear, footwear, or both resulted in slight decrements in the distances traversed. However, the subjects' responses on the questionnaire indicated that the headgear and the footwear each represented a greater hindrance to task performance than did the overgarment alone.

There are features of both the mask and the overboots that may well have made the Railwalk a more difficult task to perform when these items were worn. For example, the visual field testing reported previously revealed that the nasal and the inferior portions of the field, in particular, are restricted by the mask. Thus, it is likely that the subjects did find it difficult to view their feet or that portion of the rail immediately forward of their feet when the mask was worn. The subjects themselves consistently rated the visual restrictions imposed by the mask as being an element of at least moderate importance in interfering with their performance of the psychomotor tasks. With regard to the overboots, their relatively large dimensions may also have blocked the subjects' view of the rail to some extent. The subjects judged that the bulk and the protruding parts of the overboots were of importance in hindering Railwalk performance along with a reduced tactile sense of the relationship between the foot and the rail experienced when the overboots were worn. Thus, there are a number of mask and overboot design elements that may have influenced the subjects' perceptions regarding the difficulty of performing the Railwalk when wearing these items. However, compared with performance in the overgarment alone, the decreases in scores were small when the headgear or the footwear was used as well.

It was found in Investigation I that the subjects traversed a significantly greater distance along the rail when they were wearing the BDU than when they were wearing the MOPP IV attire. Although no statistically significant

difference was obtained when the Railwalk scores for the shorts, the BDU, and the overgarment were compared in Investigation II, the scores for the overgarment were substantially lower than those for the other two conditions. In the present investigation, use of the protective headgear, footwear, or both along with the overgarment yielded Railwalk scores that were even lower than those for the overgarment alone, although the differences among the scores were slight. Thus, there is the possibility that the poorer performance in MOPP IV attire relative to performance in the BDU, which was reported in Investigation I, was attributable to combined effects of the overgarment and the protective headgear and footwear.

Unlike the findings for the Railwalk, performance on the Pursuit Rotor was significantly affected by clothing condition in this investigation, as well as in Investigation I. This test of visual-motor coordination has been described as one involving the ability to control muscular movements in order to make fine, accurate adjustments, or to coordinate such movements with perception of a visual stimulus.[44,45] Given the nature of the task, it is likely that performance levels would be negatively affected if the protective mask impaired vision or the protective gloves reduced tactile cues. Use of either the protective headgear or the handwear did result in lowering scores somewhat compared with those for the overgarment alone. When the mask and hood were worn, there was a decrement of 4% and, when the gloves were used, there was a decrement of 3% relative to the mean time-on-target when the overgarment was worn without any additional protective items. These decreases were small and there were no significant differences among scores for the overgarment alone, the overgarment plus mask and hood, or the overgarment plus gloves. However, when the mask with hood and the gloves were worn together, the mean time-on-target was significantly lower than the means for all other conditions. Use of the mask, hood, and gloves in combination with each other resulted in a decrement of 10% relative to the mean for the overgarment alone, an amount slightly greater than the sum of the decrements associated with use of only the headgear or only the handwear.

The relative scores on the Pursuit Rotor reflected the subjects' responses on the questionnaire regarding the extent to which performance was impaired under each clothing condition. The subjects reported essentially no impairment when they wore the overgarment without any additional protective items. When either the headgear or the handwear was also worn, the ratings approached the level of moderate impairment. They exceeded this level when the headgear and the handwear were used together.

On the basis of the scores and the questionnaire responses for the four conditions under which the Pursuit Rotor task was performed, there appears to be evidence that the mask and the gloves limited visual and tactile cues, respectively, with the result being that performance was poorest and the task most difficult to execute when both the headgear and the handwear were worn. An additional consideration is the impact that the overgarment had on task performance.

It was found in Investigation II that the mean score achieved when the overgarment was worn differed by less than 1 second from the mean achieved when the T-shirt and shorts were used. However, the mean time-on-target obtained in Investigation III for the condition in which the mask with hood and the gloves were worn with the T-shirt and shorts was better, by approximately 6 seconds, than the mean obtained in the present investigation for the condition in which the headgear and the handwear were worn with the overgarment. This finding would seem to indicate that the overgarment had a negative effect on Pursuit Rotor performance, at least when vision and tactility were limited by use of the mask and the gloves, respectively.

In this investigation, as in the others that included the protective gloves, the worst performance on the Purdue Pegboard Assembly Test occurred when the handwear was worn. The relationship among the scores on the Purdue Assembly Test was the same for Investigation III, the investigation in which the T-shirt and shorts were used, but the protective overgarment was not. That is, the best scores were obtained when the torso clothing was worn alone or with the mask and hood, and the means for these two conditions did not differ significantly from each other. The means for the two conditions in which gloves were used also did not differ significantly from each other, but they were significantly poorer than those for the two conditions that did not include handwear. Mean times to task completion with the gloves were more than triple those achieved when the hands were bare. Thus, in the present investigation, as in Investigation III, performance on the Purdue Pegboard Assembly Test was not affected by the wearing of the mask and hood. Indeed, in both investigations, scores were somewhat better, though not significantly so, when the headgear was worn with the gloves than when it was not.

With regard to the other manual dexterity task, the O'Connor Finger Dexterity Test, the worst performance levels were again associated with the two conditions in which the gloves were used. Relative to the best mean score, that achieved when the overgarment was worn without any additional protective components, mean time to task completion increased by 5% when the mask and hood were used as well. The means for these two conditions did not differ significantly from each other, but they were significantly better than the mean score achieved when the gloves were used with the overgarment. With the handwear, mean time to task completion increased by 47% relative to the mean for the overgarment alone. The results obtained for the condition that included both the headgear and the handwear were at variance with those obtained on the O'Connor Test in Investigation III and with those for the Purdue Assembly Test insofar as the mean for this condition was significantly worse than the mean for all others. When the mask and hood and the gloves were used together, mean time to task completion increased by 72% relative to the mean for the overgarment alone, an amount greater than the sum of the decrements associated with use of either the headgear or the handwear. Therefore, it appears that the mask and hood, when worn in combination with the overgarment and the gloves, had a negative effect on performance of the O'Connor Test.

The finding that scores on the O'Connor and the Purdue Assembly Tests were poorer when gloves were worn than when the hands were bare indicates that the

gloves impaired fine finger manipulation, the primary component of both tasks.[42] Visual cues, as well, have been found to be important for the successful completion of the O'Connor Test, whereas performance of the Purdue Assembly Test is not as heavily dependent upon the visual component.[43] The finding that use of the mask and hood along with the overgarment and the gloves yielded a mean score on the O'Connor Test that was significantly worse than the means for the other conditions and that, on the Purdue Assembly Test, the score when the headgear and the handwear were worn did not differ from the score when the handwear was worn and the headgear was not may be a reflection of the relative importance of visual information to execution of the two tasks.

On the questionnaire, the ratings assigned to the manual dexterity tasks did not reveal that the subjects experienced greater difficulty performing the O'Connor Test while wearing the mask and hood than they did performing the Purdue Assembly Test. However, the questionnaire responses did indicate that certain design characteristics of the mask, such as its weight and protruding parts, were of greater importance in interfering with the psychomotor coordination tasks when the gloves were used as well than they were when the headgear was worn and the gloves were not. Likewise, characteristics associated with the gloves, such as finger lengths and flexibility, were rated by the subjects as being of greater importance in interfering with performance when the mask and hood were also worn than when the gloves were used and the mask and hood were not. Thus, although the questionnaire results failed to distinguish between the two dexterity tasks in terms of the extent to which the mask and hood hindered performance, the results do indicate that the subjects experienced greater difficulty on the psychomotor tasks when they wore the headgear and the handwear together than when only the headgear or only the handwear was used.

Given the scores on the O'Connor Test and the subjects' responses on the questionnaire, it appears that any visual problems associated with the mask were not of themselves sufficient to result in more than small performance decrements and slight increases in perceived difficulty of the task relative to performance with the overgarment alone. However, when the gloves, as well as the mask, were worn, the mean time to task completion on the O'Connor Test was significantly poorer than the means for all other conditions and, in the subjects' opinions, performance approached the level of extreme impairment. These findings may reflect the components underlying the O'Connor Test to the extent that visual cues are likely to become more critical as fine finger dexterity is diminished. However, the possibility that the overgarment had a negative effect on the O'Connor Test must also be considered because of some findings from Investigation III.

In Investigation III, scores achieved on the O'Connor Test when the mask, the hood, and the gloves were worn with the T-shirt and shorts did not differ significantly from, and were even slightly better than, the scores achieved when the gloves were worn and the headgear was not. Analysis of the O'Connor test in Investigation II also failed to yield a significant difference among scores as a function of torso clothing. That is, there was no evidence that use of the overgarment hindered performance on the O'Connor Test to a greater extent than did use of the T-shirt and shorts or the BDU. There are no obvious design characteristics of the overgarment that may have had a deleterious effect on

performance when the headgear and the handwear were worn together, but not when each was worn separately. However, from the results of the present investigation, it appears that some aspect of the overgarment may have contributed toward impaired performance on the O'Connor Test, at least when both vision and tactility were limited by use of the mask and the gloves, respectively.

The O'Connor Finger Dexterity Test is not the only psychomotor coordination task the performance of which may have been negatively influenced by the combined effects of the overgarment, the mask, and the gloves. The other, as was mentioned previously, is the Pursuit Rotor. Vision is an important component of both these tasks.[43,44,45] It may be that the subjects' view of these tasks was obscured by the relatively bulky sleeves of the overgarment coat, further aggravating a situation in which visual and tactile cues were already limited by the mask and the gloves. Although the mask, the gloves, and the overgarment may all have contributed to some extent toward performance decrements on the O'Connor and the Pursuit Rotor, there was no evidence that any item other than the protective gloves impaired performance on the Purdue Pegboard Assembly Test. The Railwalk was the only psychomotor task that involved use of the overboots and the only psychomotor task for which a significant clothing effect was not obtained. However, there were trends in the data for this task to indicate that performance levels were negatively affected by use of the mask, the overboots, or both with the overgarment.

Investigation V. Comparison of MOPP Levels

Clothing conditions and tasks. A total of four clothing conditions comprised this investigation. These were the four levels of Mission-Oriented Protective Posture, referred to as MOPP I through IV.[30] The protective overgarment, worn over the T-shirt and gym shorts, was common to each clothing condition, as were combat boots. The conditions and their MOPP designations were:

1. Overgarment (MOPP I).
2. Overgarment, overboots (MOPP II).
3. Overgarment, overboots, mask with hood (MOPP III).
4. Overgarment, overboots, mask with hood, gloves (MOPP IV).

Investigation I was a comparison of the effects of one MOPP level, MOPP IV, and the BDU on the body mobility and the psychomotor coordination tasks. Some of the clothing conditions compared in Investigation IV also corresponded to MOPP levels, but others did not. Because of the impact that variations in MOPP level may have on the functioning of soldiers on the battlefield, the present investigation included only those combinations of chemical protective items that comprise the levels of MOPP.

Each body mobility and each psychomotor task was performed under the extreme MOPP levels, MOPP I and MOPP IV. Some were also performed under MOPP levels II or III or both. The MOPP conditions tested for each task are presented in Table 32.

TABLE 32. Tasks Performed Under Each MOPP Level in Investigation V

Task	MOPP Level I	II	III	IV
Body Mobility				
1. Standing Trunk Flexion	o	o	o	o
2. Upper Arm Abduction	o	o	o	o
3. Upper Arm Forward Extension	o	o	o	o
4. Upper Arm Backward Extension	o	o	o	o
5. Upper Leg Flexion	o	o		o
6. Upper Leg Forward Extension	o	o		o
7. Upper Leg Abduction	o	o		o
8. Upper Leg Backward Extension	o	o		o
9. Ventral-Dorsal Head Flexion	o			o
10. Head Rotation	o			o
Psychomotor Coordination				
11. Pursuit Rotor	o			o
12. O'Connor Finger Dexterity	o			o
13. Purdue Pegboard Assembly	o			o
14. Railwalk	o	o	o	o

Results. The mean scores on each body mobility and each psychomotor task for the MOPP levels are presented in Table 33. For those tasks on which two levels were compared, the results of the t tests for small, correlated samples are included in Table 33, whereas, for those tasks on which three or more levels were compared, the F ratios for the main effect of MOPP level obtained in the analyses of variance are included.

It can be seen in Table 33 that significant differences in performance as a function of MOPP level were obtained for two of the body mobility tasks, Ventral-Dorsal Head Flexion and Head Rotation. On each of these tasks, the extent of the head movement was greater in the MOPP I than in the MOPP IV attire. The analyses performed on the remaining mobility tasks did not yield statistically significant effects of MOPP level. On Upper Leg Forward Extension, Abduction, and Backward Extension and on Standing Trunk Flexion, the mean scores for MOPP IV are slightly inferior to those for the other MOPP levels. However, the differences among the means for the MOPP levels are small.

Scores on two of the four psychomotor tasks were significantly affected by MOPP level. These tasks are the O'Connor Finger Dexterity and the Purdue Pegboard Assembly Tests. In each instance, mean time to task completion is faster in MOPP I than in MOPP IV. The results of the t test performed on the scores for the Pursuit Rotor approached significance ($p<.10$) with the mean time-on-target in MOPP I attire being superior to that in MOPP IV attire. On the Railwalk, the mean distances traversed under MOPP levels I, II, and III are substantially greater than the distance traversed under MOPP IV. However, the analysis of variance performed on this task did not yield a main effect of MOPP level that even approached significance.

Median ratings for Section I of the questionnaire are presented in Table 34. The subjects' responses on this section of the questionnaire were subjected to Wilcoxon tests (T) if two MOPP levels were involved and to Friedman tests (χ_r^2) if at least three MOPP levels were to be compared. The results of the tests are included in the table.

As can be seen in Table 34, the medians for MOPP I are relatively low and indicate that, in the subjects' opinions, performance of the body mobility and the psychomotor tasks was at most slightly impaired by use of the overgarment without any additional protective items. On some of the body mobility tasks that were performed under at least three MOPP levels, the medians increase as the level of protection increases. However, for those body mobility tasks on which the Friedman test was performed, there were no significant differences among the rank orderings of the subjects' ratings as a function of MOPP level (Table 34).

The body mobility tasks with the highest median ratings are Ventral-Dorsal Head Flexion and Head Rotation. The median for the former indicates that the subjects found their performance to be moderately impaired in MOPP IV. The median for the latter exceeds the moderate level of impairment (Table 34). The Wilcoxon tests executed on the data for the two head movements revealed that the ratings that the subjects assigned to the MOPP IV condition differed significantly from the ratings assigned to the MOPP I condition (Table 34).

TABLE 33. Mean Scores for Body Mobility and Psychomotor Tasks Under Each MOPP Level

Task	MOPP Level				t[a]	F
	Body Mobility					
1. Standing Trunk Flexion (cm)	III	I	II	IV		
	2.07	2.37	2.67	2.70	-	<1.00[b]
2. Upper Arm Abduction (deg.)	IV	III	II	I		
	147.02	145.48	144.82	142.93	-	<1.00[c]
3. Upper Arm Forward Extension (deg.)	I	III	IV	II		
	152.20	151.93	150.54	149.18	-	1.24[c]
4. Upper Arm Backward Extension (deg.)	IV	I	II	III		
	38.52	37.68	37.00	36.61	-	<1.00[c]
5. Upper Leg Flexion (deg.)	II	IV	I			
	77.04	75.09	74.11		-	<1.00[d]
6. Upper Leg Forward Extension (deg.)	II	I	IV			
	64.64	64.36	62.09		-	1.00[d]
7. Upper Leg Abduction (deg.)	II	I	IV			
	52.61	52.07	51.39		-	<1.00[d]
8. Upper Leg Backward Extension (deg.)	II	I	IV			
	40.66	40.54	39.73		-	<1.00[d]
9. Ventral-Dorsal Head Flexion (deg.)	I	IV				
	139.18	120.25			6.27*	-
10. Head Rotation (deg.)	I	IV				
	147.93	106.32			8.82*	-

TABLE 33. Mean Scores for Body Mobility and Psychomotor Tasks Under Each MOPP Level (cont'd)

Task	MOPP Level				t^a	F
	Psychomotor Coordination					
11. Pursuit Rotor (sec)	I 100.31	IV 95.32			2.08	-
12. O'Connor Finger Dexterity (sec)	I 71.58	IV 105.72			7.39*	-
13. Purdue Pegboard Assembly (sec)	I 53.86	IV 170.55			4.76*	-
14. Railwalk (cm)	I 168.86	III 167.02	II 165.70	IV 134.98	-	2.33[c]

NOTE: MOPP levels connected by the same line are not significantly different ($p > .05$).

[a] $df = 10$
[b] $df = 3,27$
[c] $df = 3,30$
[d] $df = 2,20$

*$p < .001$

TABLE 34. Median Ratings of the Impairment of Body Mobility and Psychomotor Tasks Under Each MOPP Level

Task	MOPP Level I	II	III	IV	T	(N)	χ_r^2
Body Mobility							
1. Standing Trunk Flexion	1.3	1.4	1.5	1.2	-	-	1.44[a]
2. Upper Arm Abduction	1.3	1.8	2.0	2.0	-	-	4.71[a]
3. Upper Arm Forward Extension	1.8	1.9	1.9	1.8	-	-	2.32[a]
4. Upper Arm Backward Extension	1.3	1.6	1.7	2.4	-	-	4.66[a]
5. Upper Leg Flexion	1.7	1.9	-	2.1	-	-	2.23[b]
6. Upper Leg Forward Extension	1.7	1.8	-	2.4	-	-	3.45[b]
7. Upper Leg Abduction	1.7	1.9	-	2.0	-	-	0.59[b]
8. Upper Leg Backward Extension	1.6	2.0	-	2.2	-	-	0.95[b]
9. Ventral-Dorsal Head Flexion	1.2	-	-	3.0	0.0**	(9)	-
10. Head Rotation	1.2	-	-	3.6	0.0**	(10)	-
Psychomotor Coordination							
11. Pursuit Rotor	1.3	-	-	3.2	5.0*	(10)	-
12. O'Connor Finger Dexterity	1.1	-	-	4.1	0.0**	(11)	-
13. Purdue Pegboard Assembly	1.0	-	-	4.6	0.0**	(11)	-
14. Railwalk	1.9	3.0	3.2	3.8	-	-	14.26**[a]

NOTE: Subjects rated the extent to which performance on each task was impaired by the clothing being worn according to the following scale: 1=not at all; 2=slightly; 3=moderately; 4=considerably; 5=extremely.

[a] $df=3$ *$p<.02$
[b] $df=2$ **$p<.01$

Among the psychomotor tasks, the O'Connor Finger Dexterity and the Purdue Pegboard Assembly Tests have the highest ratings (Table 34). The medians for these tasks indicate that the subjects judged their performance to be more than considerably impaired in the MOPP IV attire, whereas it was essentially not at all impaired in the MOPP I attire. The Wilcoxon tests for the two manual dexterity tests yielded significant differences between the ratings assigned to these two MOPP levels. The Wilcoxon test performed on the subjects' ratings for the Pursuit Rotor also yielded a significant difference between the ratings assigned the MOPP I and the MOPP IV levels of protection (Table 34). The median for MOPP I indicates that the subjects experienced essentially no impairment in the overgarment, whereas the median for MOPP IV indicates that they found their performance to be moderately impaired when all protective items were being worn. On the Railwalk, the median ratings increase as MOPP level increases with the median for MOPP IV approaching the level of considerable impairment. The results of the Friedman test performed on the Railwalk data indicate that there were significant differences among the rank orderings of the ratings that the subjects assigned to the MOPP levels (Table 34).

The medians for the bipolar adjectives in Section IV of the questionnaire are presented in Table 35. Included there are medians calculated from the subjects' ratings during mobility testing and their ratings during psychomotor testing. With the exception of a few bipolar dimensions, the median ratings for the body mobility testing are negative with the ratings of the MOPP IV level generally lying farthest from the neutral point and the ratings of the MOPP I level lying closest to the neutral point on the scale. The most extreme negative ratings, with a median approaching the very negative point on the scale, were given the MOPP IV level on the bipolar dimension of hot-cool. The Friedman test for this bipolar dimension of thermal sensation was the only one performed on the ratings that the subjects assigned while carrying out the body mobility tasks that yielded a significant difference among the rank orderings of the ratings of the MOPP levels. The medians for the hot-cold dimension reflect increasingly negative ratings with increases in MOPP level (Table 35).

A number of the Friedman tests performed on the ratings that the subjects assigned while carrying out the psychomotor tasks were significant (Table 35). For some of the bipolar dimensions with significant findings, the medians indicate that the ratings were increasingly negative as the level of protection increased. This is the case for the dimensions of comfort, flexibility, and balance. On other bipolar dimensions for which the Friedman test was significant, the ordering of the ratings does not correspond to the ordering of the MOPP levels. For example, on the dimension of hot-cool. the median for MOPP III is slightly more negative than the median for MOPP IV (Table 35).

The bipolar dimensions with the most extreme negative ratings during psychomotor testing are comfort, balance, ease of work, and degree of liking. On each of these dimensions, the median for the MOPP IV condition approaches the very negative point on the scale. Also, for the MOPP IV condition on each of these dimensions, the median associated with the psychomotor tests is more negative than the median associated with the body mobility tests (Table 35).

TABLE 35. Median Ratings of Bipolar Dimensions for Body Mobility and Psychomotor Tasks Under Each MOPP Level

Bipolar Dimension	MOPP Level I	II	III	IV	X_r^{2a}
Body Mobility					
Uncomfortable-Comfortable	-0.2	-0.6	-0.9	-1.0	2.24
Inflexible-Flexible	-0.4	-0.8	-0.6	-1.0	1.58
Heavy-Light	0.0	-0.9	-0.6	-0.9	4.94
Binding-Free moving	-0.3	-0.4	-0.8	-1.1	2.26
Hot-Cool	-0.3	-0.8	-1.6	-1.7	13.44***
Poorly balanced-Well balanced	0.0	0.0	-0.3	-0.9	1.61
Tight-Loose	-0.1	0.0	-0.1	-0.4	1.66
Flimsy-Sturdy	+0.6	+0.3	+0.7	+0.4	1.09
Poorly fitted-Well fitted	+0.2	0.0	-0.2	-0.2	1.17
Hard to work in-Easy to work in	0.0	-0.4	-0.8	-1.1	2.73
Function poorly-Function well	+0.9	+0.3	+0.7	0.0	1.17
Dislike-Like	+0.2	+0.7	0.0	-0.8	5.64
Psychomotor Coordination					
Uncomfortable-Comfortable	+0.3	0.0	-1.2	-1.6	10.34**
Inflexible-Flexible	0.0	-0.6	-1.1	-1.1	7.96*
Heavy-Light	-0.3	0.0	-1.2	-1.3	7.06
Binding-Free moving	0.0	+0.1	-1.0	-0.9	10.17**
Hot-Cool	-0.2	-0.4	-1.3	-1.2	10.50**
Poorly balanced-Well balanced	+0.4	-0.2	-0.8	-1.6	9.49*
Tight-Loose	+0.2	+0.3	-0.1	-0.4	5.64
Flimsy-Sturdy	+0.9	+0.6	+0.7	+0.7	2.51
Poorly fitted-Well fitted	+0.6	-0.2	-0.6	-0.8	2.86
Hard to work in-Easy to work in	-0.2	+0.6	-1.2	-1.8	11.37***
Function poorly-Function well	+0.7	+0.7	-0.8	-1.3	7.53
Dislike-Like	+0.6	+0.7	-1.0	-1.6	6.84

NOTE: Possible scores range from -3 to +3 with -3 indicating the extreme for the first (negative) word in the adjective pair, 0 indicating neutral, and +3 indicating the extreme for the second (positive) work in the adjective pair.

[a]$df=3$

*$p<.05$
**$p<.02$
***$p<.01$

Discussion. Some of the clothing conditions tested in Investigation IV corresponded to MOPP levels, whereas others did not. The conditions included in that investigation were selected for the purpose of examining the effects of the chemical protective mask and hood, the overboots, and the gloves when they were worn individually with the overgarment and when they were worn in combination with each other and the overgarment. The conditions tested in the present investigation were limited to those corresponding to MOPP levels in order to examine the effects of the protective items on body mobility and psychomotor coordination when the items were worn only in the combinations prescribed by Army guidance.[30]

Given the similarities between the clothing conditions included in Investigation IV and the MOPP level configurations included in the present investigation, it is not unexpected that the results of the two investigations are also similar. Again, there were no deleterious effects on performance of simple movements of the torso, the arms, or the legs associated with wearing the various combinations of chemical protective items that comprise the MOPP levels. The only mobility tasks for which a significant difference was obtained between the MOPP levels were Ventral-Dorsal Head Flexion and Head Rotation. On both tasks, the excursions of the head were greater at the MOPP I than at the MOPP IV level. Evidence from the previous investigations would indicate that the protective mask was the component of the MOPP IV attire that restricted the head movements. Specifically, the mask's cheek pouches, which extend well below the chin, appeared to limit the ventral excursion of the head, whereas rotation of the head to the right and the left was limited by contact of the ventro-lateral surfaces of the cheek pouches with the shoulders.

The Railwalk was the only psychomotor task that the subjects performed under all four levels of MOPP. The analysis of this task did not yield a significant effect of MOPP levels. However, the distances traversed along the rail under MOPP levels I, II, and III were similar and were greater by 18% to 20% than the distance traversed under the MOPP IV level. The questionnaire data indicated that the subjects experienced increased impairment of Railwalk performance as the level of protection increased. The ratings for MOPP I reflected essentially no impairment, whereas MOPP II and III ratings reflected moderate degrees of impairment, and the ratings for MOPP IV approached the level of considerable impairment.

The MOPP III and the MOPP IV conditions differ only to the extent that the protective gloves are worn under the latter level of protection, but not under the former. The presence or absence of the handwear was not expected to differentially affect Railwalk performance because the subjects merely clasped their hands behind their backs while executing this task. For this reason, Investigation IV did not include conditions for the Railwalk in which the gloves were worn alone and in combination with the mask and hood and the overboots. Because the impact of the protective handwear on Railwalk performance was not examined in detail, there is no basis for suggesting that any particular characteristics of the handwear, per se, may have resulted in the trend found in the present investigation toward Railwalk scores in MOPP IV attire being somewhat inferior to scores for the other MOPP levels. However, this finding does bear further study in view of the fact that, in this investigation and in

Investigation IV, the protective headgear and footwear, items more likely to affect Railwalk performance than the gloves, did not yield substantial decrements in Railwalk scores relative to scores for the overgarment alone.

The other psychomotor coordination tasks, the O'Connor Finger Dexterity and the Purdue Pegboard Assembly Tests and the Pursuit Rotor, were performed under the two extreme levels of protection, MOPP I and MOPP IV. On the O'Connor and the Purdue Tests, the scores for the MOPP levels differed significantly from each other and, on the Pursuit Rotor, the difference between the scores approached significance.

With regard to the Pursuit Rotor, it was found in Investigation IV that mean time-on-target was decreased significantly when the protective headgear and handwear were both worn with the overgarment relative to the mean when the overgarment was worn without these additional items. Therefore, it is not unexpected that, in the present investigation, the mean for the MOPP IV condition was inferior to the mean for the MOPP I condition. In Investigation IV, it was also found that use of the protective handwear along with the overgarment resulted in significant decrements in performance on the O'Connor and the Purdue Assembly Tests compared with scores for the overgarment alone. The finding of significant differences between MOPP levels I and IV on these manual dexterity tasks in the present investigation is in consonance with the results of Investigation IV. Use of the MOPP IV attire had a more negative impact on the Purdue Assembly Test than it did on the O'Connor Test. Relative to the mean for MOPP I, the times to task completion were increased by 47% on the O'Connor Test and by more than 200% on the Purdue Assembly Test at the MOPP IV level of protection.

The subjects' responses on the questionnaire indicated that they experienced greater difficulty performing the Pursuit Rotor and the two manual dexterity tasks in MOPP IV than in MOPP I attire. For the Pursuit Rotor, the subjects judged that there was essentially no impairment in performance associated with MOPP I, but that there was moderate impairment associated with MOPP IV. For the two manual dexterity tasks, the questionnaire responses indicated that there was again no impairment in MOPP I, whereas there was more than considerable impairment in MOPP IV.

During both the psychomotor and the body mobility testing, the ratings assigned to a number of bipolar dimensions selected to describe clothing characteristics tended to lie around the neutral point on the scale when the subjects were assessing MOPP I and generally fell in the negative region when they were assessing MOPP IV. In some instances, the ordering of the MOPP levels was reflected in the ordering of the ratings. For example, during body mobility testing, the subjects gave increasingly negative ratings to the thermal sensations they experienced as the level of protection increased. The most negative rating, that for MOPP IV, indicated that the subjects were approaching the point of feeling very hot. Thus, although the ambient temperature was maintained at 15.6°C (60°F) and the level of physical activity was quite low, the subjects did not feel thermally neutral while performing the body mobility tasks in MOPP IV attire. The most precipitous drop in the ratings of the MOPP levels occurred between MOPP levels II and III, indicating that use of the mask

and hood, in particular, was found by the subjects to be associated with their thermal discomfort.

Examination of the data for the MOPP IV condition revealed that the rating given a bipolar dimension during psychomotor testing was generally more negative than the rating given the same dimension during body mobility testing. This reflects the relative impact that MOPP IV attire had on the two categories of tasks. With regard to body mobility, simple movements of the head, but not of the trunk, the arms, or the legs, were more restricted at the MOPP IV than at the MOPP I level of protection. However, there were indications on each of the four psychomotor tasks that performance in MOPP IV attire was inferior to performance in MOPP I attire with the differences between these extreme MOPP levels being greatest on the manual dexterity tasks.

The particular chemical protective items that may have affected performance of the psychomotor tasks were examined in Investigation IV, as were the impacts of interactions among items. The results of the present investigation, because they were couched in terms of MOPP levels rather than in terms of items of attire, emphasize the fact that a penalty for increasing the level of protection from MOPP I to MOPP IV is a decrement in visual-motor and manual dexterity capabilities.

General Discussion

As a subject completed all body mobility testing associated with the series of five investigations, he was asked to indicate the one item out of all those worn that had hindered performance of the simple body movements to the greatest extent. Five of the subjects chose the protective overgarment and six chose the mask. The selection of these items is not surprising in light of the relative effects of clothing conditions on mobility performance and the subjects' reports regarding the items as they executed the tasks.

The subjects had the opportunity to carry out the mobility tasks while wearing three configurations of torso clothing -- the T-shirt and gym shorts alone, with the BDU, and with the overgarment. Although the task involving displacement of the upper arm in the body's frontal plane was the only one on which scores for the overgarment were significantly poorer than those for the BDU, there were no instances in which mobility performance in the overgarment was significantly better than that in the BDU. While performing the mobility tasks, the subjects also rated the overgarment more negatively than they did the BDU in terms of flexibility at the shoulder, garment bulk, crotch length, and other characteristics.

The overgarment was designed to be worn as the outermost garment over other clothing items and it is, therefore, cut more fully than the BDU. In addition, the overgarment is fabricated of several layers of materials, whereas the BDU is made of a single layer. Because of these factors, the protective overgarment is, as the subjects' responses indicate, a looser-fitting and bulkier garment than the BDU. Within the constraints of the functional concept and the protective material requirements, it may still be possible to improve the fit and the user acceptance of the overgarment by revising the grading system so

that not only its circumferential dimensions, but its linear dimensions as well, vary with size.

Regardless of the torso clothing being worn during body mobility testing, the use of the mask and hood was associated with restricted flexion and rotation of the head relative to that achieved when the head was bare. Because the mask was not tested without the hood, the contribution that the hood may have made toward limiting excursions of the head could not be assessed. However, the mask contacted the subject's body as the head was moved to extreme positions and, therefore, the mask, rather than the hood, appeared to be the headgear component responsible for restricting movements of the head. The lower portions of the mask's cheek pouches contacted the subject's chest as the head was flexed ventrally and the ventro-lateral surfaces of the cheek pouches contacted the subject's shoulders as the head was rotated. If the cheek pouches had extended to the level of the subject's chin and not beyond toward the chest, it is highly probable that angular displacement of the head when the mask was worn would have more closely approximated the amount of displacement exhibited when the head was bare.

In contrast to the performance effects and the subjects' observations when the mask or the overgarment were used, there were no indications that the protective overboots or the gloves influenced execution of any body mobility tasks. In addition, there was no evidence that the hood bound the shoulder or the upper arm or in any other way constrained the movements. Thus, the fact that the subjects selected either the overgarment or the mask when forced to choose the one item that had the most deleterious effect on execution of simple body movements is a reflection of their performance and experiences with the clothing conditions to which they were exposed.

Upon the completion of psychomotor testing, the subjects again indicated the one item that they felt had been most important in impairing their performance on this category of tasks. The gloves were selected by five subjects and the mask by six. As was the case with the items chosen by the subjects upon the completion of body mobility testing, the selections are in consonance with the relative effects of clothing conditions on the subjects' performance of the psychomotor tasks and the subjects' reports regarding the items as they executed the tasks.

Scores on the two manual dexterity tests were significantly poorer when the protective gloves were worn than when the hands were bare, regardless of which other protective items were also being worn. Among the handwear characteristics identified by the subjects as having interfered with their performance were the thickness, the finger lengths, and the impaired feel associated with the gloves.

The gloves used in this investigation were made of butyl rubber and were 0.64 mm (25 mil) thick. Bensel and Bassett[46] conducted a study to evaluate this and other versions of the protective handwear with regard to their differential effects on manual performance. Among the handwear included in the study were butyl rubber gloves made over the same porcelain hand forms used to produce the gloves tested in the present investigations. However, these other butyl gloves were only 0.36 mm (14 mil) and 0.18 mm (7 mil) thick. Bensel and Bassett found

that dexterity improved as glove thickness was decreased. These findings indicate that, in the present investigation, the subjects' performance levels on the dexterity tasks could have been improved had the handwear been thinner, even if the dimensions of the gloves had not been changed to address the subjects' dissatisfaction with the fit of the gloves' fingers.

The difficulties that the subjects encountered with the mask led six of them to select it as the item that interfered most with performance on the psychomotor coordination tasks. As was mentioned previously, the effects of the gloves were such that scores on the dexterity tasks were significantly worse when the handwear was used than when the hands were bare, regardless of the other protective items being worn. There was not, however, a clear distinction on any psychomotor task between scores for the mask and scores for the bare-head conditions. For example, whether the torso clothing consisted of the T-shirt and shorts or the overgarment, the differences between scores for the torso clothing alone and scores for the torso clothing plus the mask and hood were not significant. There was evidence from two of the psychomotor tasks that the mask did indeed contribute toward the lowering of performance levels when it was worn in combination with other protective items. On both the Pursuit Rotor and the O'Connor Finger Dexterity Test, the use of the mask and the gloves with the overgarment resulted in scores that were significantly poorer than those for the overgarment alone, the overgarment plus the headgear, or the overgarment plus the handwear. Thus, performance on these tasks reflected an interactive effect among the items. The subjects' responses on the questionnaire also indicated that certain design characteristics of the mask, including its weight, protruding parts, and the size and shape of the lenses, were more important in impairing performance on the psychomotor tasks when the gloves were also being used than when the hands were bare.

It was found in the visual field testing that the field was restricted to some extent when the mask was worn relative to that when the head was bare, with the greatest restrictions being in the nasal and the inferior regions. It appeared that the nose cup in the mask's interior or that part of the voicemitter assembly on the exterior of the mask restricted the nasal and the inferior portions of the visual field beyond the limitations imposed by the shape and the dimensions of the lens itself. The body mobility testing revealed that rotation and ventral flexion of the head were more limited when the mask was worn than when the head was bare because of the design and the dimensions of the mask's cheek pouches. The psychomotor performance scores and the subjects' perceptions of task difficulty reveal that these factors, while they may not of themselves have had an extremely detrimental effect on performance, may have resulted in extensive decrements in psychomotor performance when combined with the reduced tactility associated with the handwear and the encumbrances on the torso associated with the protective overgarment. If this is the case, it would be expected that the mask would not have contributed to the extent that it did toward poorer psychomotor performance or increased perceptions of task difficulty had the exterior surface of its voicemitter assembly been closer to the plane of the eyes and its cheek pouches extended only to the level of the chin.

Aside from the protective gloves and the mask, there were no indications that the other protective items worn while the subjects performed the psychomotor coordination tasks affected performance of the tasks. Scores did not differ significantly as a function of which one of the three torso clothing configurations was used nor were Railwalk scores when the overboots were worn significantly different from those achieved when the footwear consisted only of combat boots. However, there were indications in the responses on the questionnaire that the subjects found it more difficult to perform the psychomotor tasks when wearing the overgarment than when wearing the T-shirt and shorts or the BDU and when wearing the overboots, rather than just the combat boots.

The objective and the subjective data that were acquired in these investigations served to identify the effects that use of individual CP items and combinations of items had on body mobility and on psychomotor coordination. By employing this approach, it has been possible to consider those particular design and dimensional aspects of the items that may have led to impaired performance levels or influenced the subjects' opinions regarding the manner in which the chemical protective attire hindered their performance. When viewed in the context of the functioning of the soldier in a chemical warfare environment, the findings indicate that use of the complete chemical protective system limits the mobility and the psychomotor coordination capabilities of the individual soldier to a greater extent than does use of a field duty uniform, such as the BDU and combat boots. More importantly, it has been found in these investigations that, as the level of the soldier's protective posture is increased, the protective items comprising the levels may interact to yield more extreme performance impairments than would be expected by simply combining the effects of the individual items. Thus, the MOPP IV level of protection is not simply the addition of the protective gloves to an ensemble already consisting of the overgarment, the mask, and the overboots. It is, rather, the diminution of the manual dexterity capabilities and tactile cues of soldiers who are already encumbered by relatively bulky torso clothing and footwear, who have a limited visual field, and who are restricted in the extent to which they can move their heads to compensate for the reduced field of vision.

As was mentioned previously, the environmental conditions and the protocol for the body mobility and psychomotor testing were established to minimize the thermal burden imposed by the protective items so that the effects of the design and the material configurations of the items themselves could be investigated. Although the test area was maintained at $15.6^{\circ}C$ ($60^{\circ}F$), the subjects indicated on the questionnaire that, while performing the body mobility tasks, they felt somewhat to very hot when outfitted in the mask and hood along with the overgarment. Given the nature of the mobility tasks and the fact that the subjects required only about 15 minutes to accomplish all tasks under a single clothing condition before they sat to complete the questionnaire, it is unlikely that their feelings of thermal discomfort influenced their performance. However, in future work of this kind involving use of the mask and hood, it would be advisable to lower the ambient temperature in the test area somewhat, to perhaps $12.8^{\circ}C$ ($55^{\circ}F$), and to allow subjects a short break midway through body mobility testing during which time they would remove the headgear. Using this approach, it may be possible to avoid the discomfort experienced by the subjects in this study.

CONCLUSIONS AND RECOMMENDATIONS

The major findings from this study as they relate to the components of the chemical protective system are as follows:

1. Overgarment: The overgarment restricted simple movements of the leg in the body's sagittal plane relative to use of the T-shirt and shorts and movement of the arm in the body's frontal plane relative to the T-shirt and shorts and the BDU. There was evidence as well that the overgarment interacted with other protective items to impede psychomotor coordination capabilities.

It may be possible to revise the grading rules for the overgarment producing a better, less bulky fit while, at the same time, maintaining a garment that can be used as the outermost layer over other clothing items.

2. Mask: The mask interfered with the capacity of the wearer's speech to be understood, restricted the visual field, particularly in the nasal and the inferior regions, and limited head rotation and ventral flexion. The mask also interacted with the protective gloves and, possibly, other protective items, to impede psychomotor coordination capabilities.

A voicemitter developed to improve speech communication might also improve the field of vision if the external surface of the voicemitter was closer to the plane of the eyes. Also a reduction in the extent to which the cheek pouches protrude below the level of the wearer's chin would increase the range of head movement possible.

3. Hood: Use of the hood and the mask interfered with the capacity of the wearer to understand spoken words. Although the body mobility and the psychomotor testing did not include an assessment of the effects of the hood independent of the mask, there were no indications that the hood restricted simple body movements or contributed toward impaired psychomotor capabilities.

The contribution that the mask may make, worn with and without the hood, to the wearer's ability to understand spoken words should be assessed. Acoustic transmission properties associated with permeable, as well as impermeable, hood materials should also be investigated.

4. Overboots: The overboots, per se, did not restrict simple body movements or result in significant reductions in psychomotor performance. However, it was reported that the overboots increased the difficulty of executing a task requiring coordinated movements of the legs and feet.

It is likely that reduction of the bulk and protrusions of the overboots would make coordinated movements of the legs and feet easier for the wearer.

5. Gloves: The gloves impaired manual dexterity capabilities and may also have interacted with other protective items to negatively affect other tasks requiring coordinated hand movements.

It is expected that a reduction in glove thickness would result in dexterity performance when handwear is worn more closely approximating performance when the hands are bare.

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APPENDIX A

BODY MEASUREMENT TECHNIQUES

APPENDIX A. Body Measurement Techniques

The techniques used to obtain the body dimensions of the subjects in this study were based upon those employed by White and Churchill[47] in their 1966 anthropometric survey of US Army men and by Churchill, McConville, Laubach, and White[48] in their 1970 survey of US Army male aviators. The equipment consisted of a 2-meter steel tape (K&E Tip-Top Wyteface), an anthropometer (GPM), a sliding caliper (Gneupel), a spreading caliper (GPM), and a balance scale. All subjects wore shorts and socks while measurements were taken. Before measurements were taken, specific body landmarks were marked on each subject with an eyebrow pencil (Maybelline, velvet black) to aid in measuring techniques. The landmarks were: Neck-Shoulder (right), Acromion (right), Stylion (right), Suprasternale, Waist (front, back, right), Cervicale, Scye (Anterior - right; Posterior - right, left), Patella (right), Sellion, Menton, and the maximum protrusion of the deltoid muscles (right). The body measurements taken and the techniques employed are presented below.

Stature

The subject stands erect, with heels together, head level, and weight distributed equally on both feet. With the arm of the anthropometer firmly touching the scalp, measure the vertical distance from the floor to the top of the head.

Shoulder Length

The subject stands erect, with heels together and head level. With a steel tape, measure the distance along the upper surface of the right shoulder, from the right lateral-neck landmark to the outer point (acromion) of the shoulder.

Sleeve Inseam Length

The subject stands erect, head level and right arm abducted with palm facing forward. With a steel tape, measure the distance along the inner surface of the right arm, from the arm scye crease to the ulnar crease. The tape is held tense and does not follow the surface contour of the arm.

Waist Front Length

The subject stands erect, with heels together. With a steel tape, measure the surface distance from the suprasternale to the anterior waist landmark.

Waist Back Length

The subject stands erect, with heels together and head level. With a steel tape, measure the surface distance along the spine from the cervicale landmark to the posterior waist landmark.

Interscye

The subject stands erect, with arms relaxed at his sides. With a steel tape held in a horizontal plane, measure the distance across the surface of the back between the right and left posterior scye landmarks.

Interscye, Maximum

The subject stands erect, with arms extended forward at a 90-degree angle from the torso. Measure the surface distance across the back between the right and left posterior scye landmarks with a steel tape.

Arm Scye Circumference

The subject stands erect, looking straight ahead, with his right arm initially raised and then lowered after the tape is in place in the axilla. The vertical circumference of the scye is measured, passing the steel tape under the right armpit and over the outer point (acromion) of the right shoulder.

Shoulder Circumference

The subject stands erect, with heels together, head level, and arms relaxed at sides. With a steel tape held in a horizontal plane, measure the circumference of the body at the level of the deltoid landmark. The reading is made at the average point of quiet respiration.

Chest Circumference

The subject stands erect, looking straight ahead, heels together, and weight distributed equally on both feet. The arms are initially raised to allow clearance of a steel tape between the arms and trunk and then relaxed. Holding the tape in a horizontal plane, measure the circumference at the level of the nipples. The reading is made at the average point of quiet respiration.

Waist Circumference

The subject stands erect, looking straight ahead, heels together, and weight distributed equally on both feet. With a steel tape held in a horizontal plane, measure the circumference of the trunk at the level of the waist (omphalion) landmarks. The reading is made at the average point of quiet respiration. The subject must not pull in his stomach.

Hip Circumference

The subject stands erect, with heels together and head level. With a steel tape measure the horizontal circumference of the hips at the level of the maximum posterior protrusion of the buttocks.

Upper Thigh Circumference

The subject stands erect, with heels approximately 10 cm (3.9 in.) apart and weight distributed equally on both feet. With a steel tape held in place perpendicular to the long axis of the right thigh, measure the circumference of the thigh at the level at the gluteal furrow.

Calf Circumference

The subject stands erect, heels approximately 10 cm (3.9 in.) apart, and weight distributed equally on both feet. With a steel tape held in a plane perpendicular to the long axis of the lower right leg, measure the maximum circumference of the calf.

Ankle Circumference

The subject stands erect, heels approximately 10 cm (3.9 in.) apart, and weight distributed equally on both feet. Measure the minimum circumference of the ankle with the steel tape being held in a plane perpendicular to the long axis of the right lower leg.

Acromion Height

The subject stands erect, with heels together and head level. With an anthropometer, measure the vertical distance from the floor to the outer point (acromion) of the right shoulder.

Waist Height

The subject stands erect, with heels together and head level. With an anthropometer to the right of the subject, measure the vertical distance from the floor to the right lateral waist landmark.

Crotch Height

The subject stands erect, with feet initially apart and then together after the anthropometer is in place. With the anthropometer in front of the subject, measure the vertical distance from the floor to the crotch. The anthropometer arm is firmly in contact with the highest point in the crotch.

Kneecap Height

The subject stands erect, with heels together. With an anthropometer, measure vertical distance from the floor to the upper edge of the right kneecap (patella).

Head Circumference

The subject sits erect, with head level. With a steel tape passing just above the bony brow ridges of the forehead, measure the circumference of the head.

Face Length

The subject sits erect, with head level, mouth closed, and jaw relaxed. With a sliding caliper, measure the vertical distance from the tip of the chin (menton) to the deepest point of the nasal root depression between the eyes (sellion).

Face Breadth

The subject sits erect, with head level. Using spreading calipers, the maximum horizontal breadth of the face is measured between the lateral projections of the cheek bones (zygomatic arches).

Interpupillary Breadth

The subject sits erect, with head level. With a sliding caliper, measure the horizontal distance from the center of the pupil of the right eye to the center of the pupil of the left eye.

Hand Length

The subject sits, with his right hand and fingers extended, palm up. With the bar of the sliding caliper parallel to the long axis of the hand, measure the distance from the wrist crease to the tip of the middle finger.

Palm Length

The subject sits, with his right hand and fingers extended, palm up. With a sliding caliper, measure the distance from the wrist crease to the skin crease at the base of the middle finger. The measure is taken parallel to the long axis of the hand.

Thumb Crotch Height

The subject sits, with his right hand and fingers extended, palm up, and with his thumb extended away from his hand. The length of the thumb crotch is measured from the skinfold at the base of the thumb to the notch between the first and second fingers. A sliding caliper is used.

Hand Circumference

The subject's right hand is extended and the thumb is held away from the fingers. The circumference of the right hand is measured with a steel tape passing over the metacarpal-phalangeal joints of the index and the little fingers.

Wrist Circumference

The subject's right hand is extended. The minimum circumference of the wrist is measured at the level of the wrist using a steel tape.

Weight

The subject is weighed, standing on a scale, while wearing gym shorts. Weight is recorded to the nearest 0.1 kg.

APPENDIX B

PHOTOGRAPHS OF CP CLOTHING ITEMS

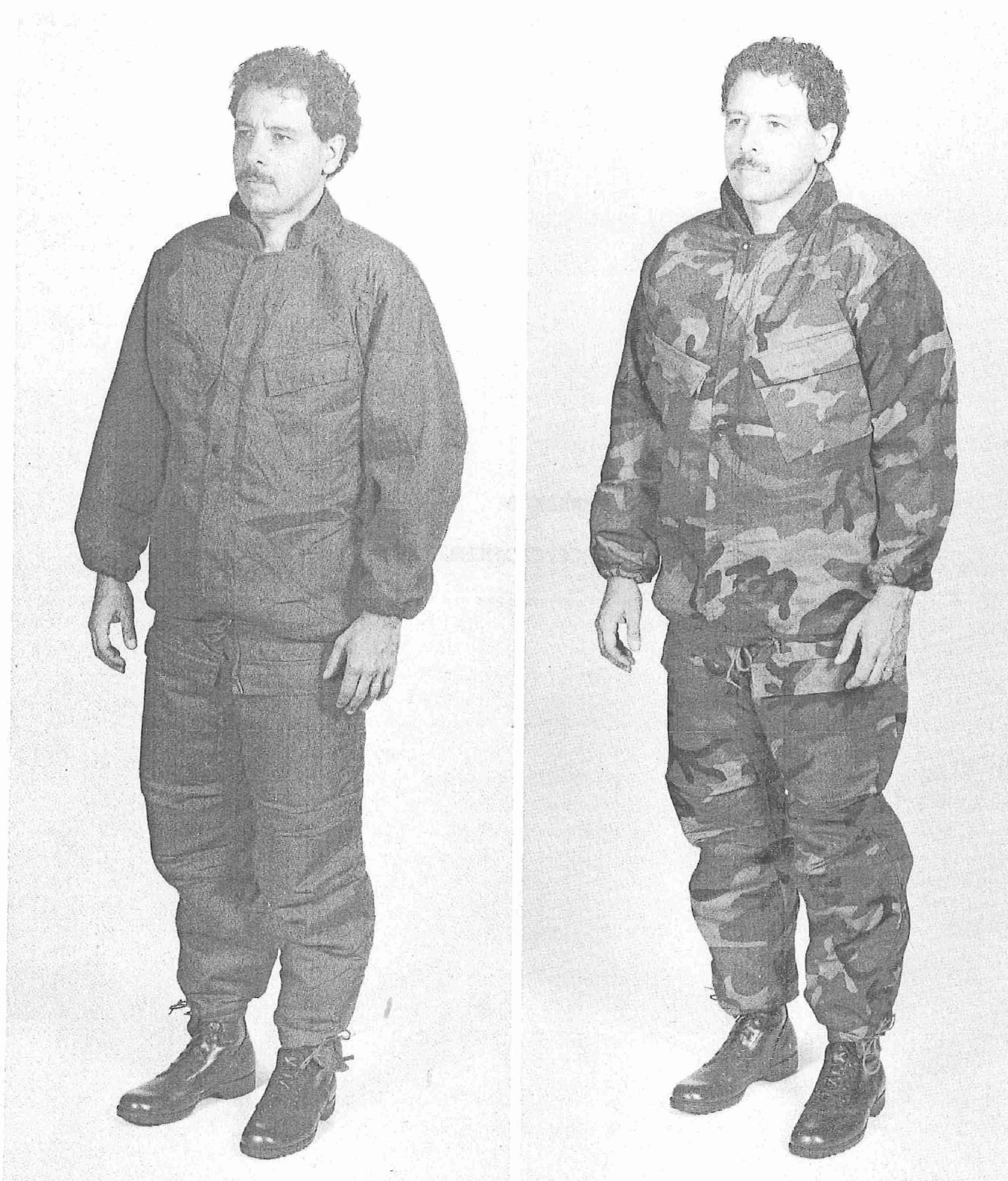

Figure B-1. Olive green CP overgarment (left) and camouflage overgarment (right).

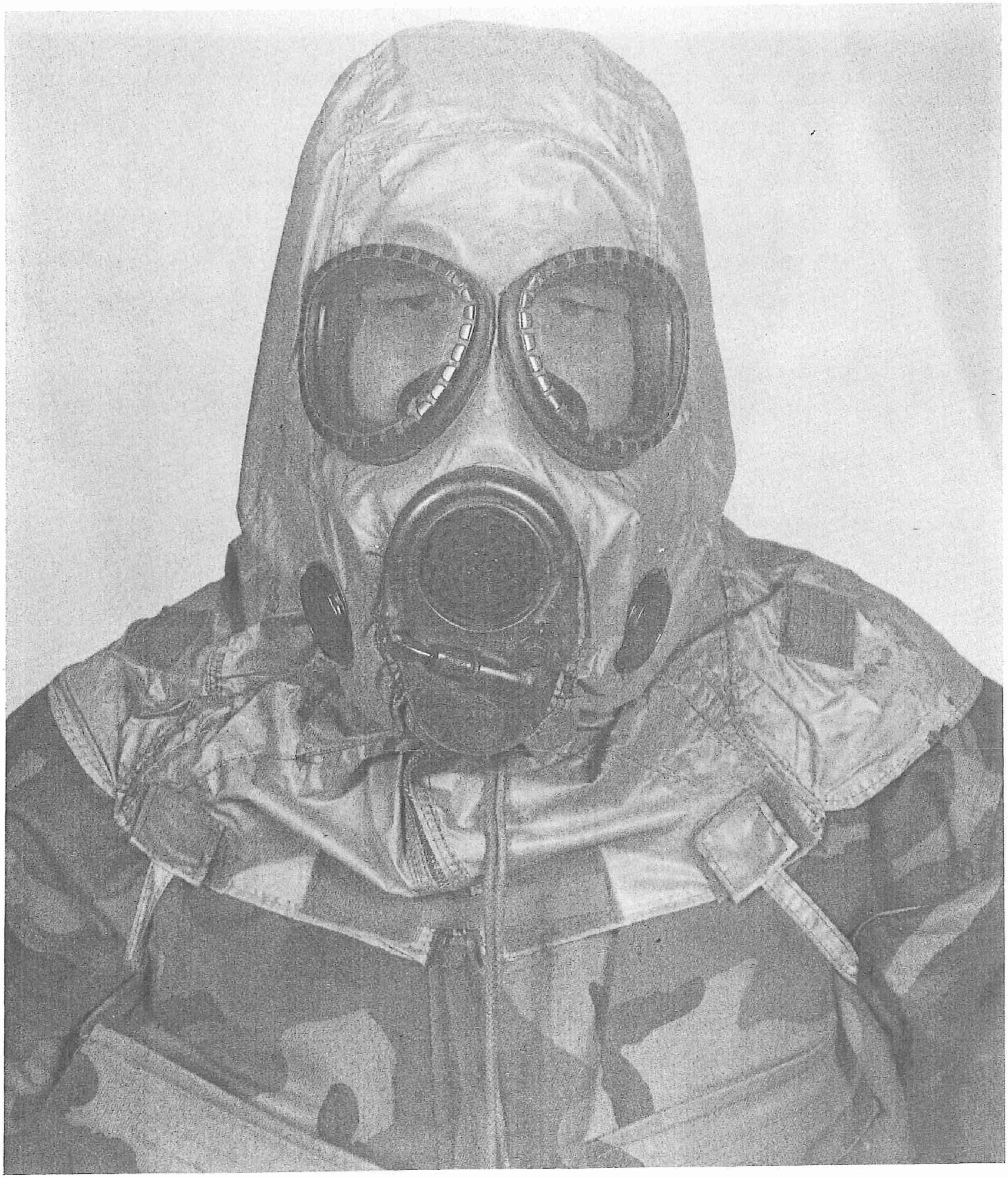

Figure B-2. CP mask and hood.

Figure B-3. CP overboots.

Figure B-4. CP gloves.

APPENDIX C

MODIFIED RHYME TEST INSTRUCTIONS TO LISTENER, WORD LISTS, AND ANSWER SHEETS

APPENDIX C. Modified Rhyme Test Instructions to Listener, Word Lists, and Answer Sheets

Name: ______________________ Condition: ______________________

MODIFIED RHYME TEST

INSTRUCTIONS

You are going to hear some one syllable words. Each word will be presented in a sentence which will tell you its item number. For example:

Number one is tree.

Number two is mile.

The word presented will be one of six words which are printed on your answer sheet for that particular item. Your job is to identify the word presented to you by drawing a line through the word you hear. For example:

Number three is tow.

3.	ROW	~~TOW~~	LOW
	MOW	SOW	BOW

Some words will be easier to hear than others. If you are not sure what the word is, guess. Always draw a line through one of the six words for each item.

If you have any questions, ask the person running the test.

MODIFIED RHYME TEST

TALKER'S LIST

6 PRACTICE FORMS

"Number _____ is _____."

	1	2	3	4	5	6
1	PAD	PAN	PASS	PAT	PATH	PACK
2	HANG	RANG	SANG	BANG	FANG	GANG
3	HIT	KIT	SIT	WIT	BIT	FIT
4	PUFF	PUN	PUP	PUS	PUB	PUCK
5	HOT	LOT	NOT	POT	TOT	GOT
6	DUNG	DUB	DUCK	DUD	DUG	DUN
7	FIB	FIG	FILL	FIN	FIT	FIZZ
8	LANE	LATE	LAY	LACE	LAKE	LAME
9	MALE	PALE	SALE	TALE	BALE	GALE
10	SEETHE	SEED	SEEK	SEEM	SEEN	SEEP
11	DIN	FIN	PIN	SIN	TIN	WIN
12	RAKE	RATE	RAVE	RATE	RAZE	RACE
13	WENT	BENT	DENT	RENT	SENT	TENT
14	SILL	SIN	SING	SIP	SIT	SICK
15	NAME	SAME	TAME	CAME	FAME	GAME
16	DIP	DID	DIG	DILL	DIM	DIN
17	RIP	SIP	TIP	DIP	HIP	LIP
18	PEAK	PEAL	PEAS	PEAT	PEACE	PEACH
19	RAW	SAW	THAW	JAW	LAW	PAW
20	DUST	GUST	JUST	MUST	RUST	BUST
21	BEAD	BEAK	BEAM	BEAN	BEAT	BEACH
22	HOOK	LOOK	SHOOK	TOOK	BOOK	COOK
23	MASS	MAT	MATH	MAD	MAN	MAP
24	BEST	NEST	REST	TEST	VEST	WEST
25	MOP	POP	SHOP	TOP	COP	HOP

MODIFIED RHYME TEST

TALKER'S LIST

6 PRACTICE FORMS

"Number ____ is ____."

	1	2	3	4	5	6
26	PICK	PIG	PILL	PIN	PIP	PIT
27	OIL	SOIL	TOIL	BOIL	COIL	FOIL
28	BUS	BUT	BUCK	BUFF	BUG	BUN
29	SUD	SUM	SUN	SUNG	SUP	SUB
30	TAM	TAN	TANG	TAP	TAB	TACK
31	TEAM	TEAR	TEASE	TEACH	TEAK	TEAL
32	FILL	HILL	KILL	TILL	WILL	BILL
33	LED	RED	SHED	WED	BED	FED
34	COLD	FOLD	GOLD	HOLD	SOLD	TOLD
35	SAKE	SALE	SAME	SANE	SAVE	SAFE
36	PALE	PANE	PAVE	PAY	PACE	PAGE
37	REEL	EEL	FEEL	HEEL	KEEL	PEEL
38	PIG	RIG	WIG	BIG	DIG	FIG
39	HEAVE	HEAL	HEAP	HEAR	HEAT	HEATH
40	CAKE	CAME	CANE	CAPE	CASE	CAVE
41	SICK	TICK	WICK	KICK	LICK	PICK
42	BATH	BACK	BAD	BAN	BASS	BAT
43	CUB	CUD	CUFF	CUT	CUSS	CUT
44	MARK	PARK	BARK	DARK	HARK	LARK
45	HEN	MEN	PEN	TEN	THEN	DEN
46	WAY	DAY	GAY	MAY	PAY	SAY
47	SACK	SAD	SAG	SAP	SASS	SAT
48	KICK	KID	KILL	KIN	KING	KIT
49	MEAT	NEAT	SEAT	BEAT	FEAT	HEAT
50	NUN	RUN	SUN	BUN	FUN	GUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 1

"Number _____ is _____."

1.	CUD	26.	THAW
2.	DIN	27.	SICK
3.	LANE	28.	BEAT
4.	TAME	29.	LOT
5.	MOP	30.	SEEM
6.	PARK	31.	FILL
7.	HEAT	32.	HIP
8.	PIN	33.	BEST
9.	FED	34.	GOLD
10.	MASS	35.	WICK
11.	BAN	36.	SANG
12.	TEAM	37.	PEAT
13.	KEEL	38.	GUST
14.	RAZE	39.	SAFE
15.	SAP	40.	DILL
16.	THEN	41.	BUCK
17.	SUP	42.	PIG
18.	CAVE	43.	PALE
19.	FIB	44.	TACK
20.	RENT	45.	BEAD
21.	PUS	46.	PATH
22.	SALE	47.	WIT
23.	HOOK	48.	BUN
24.	TOIL	49.	DAY
25.	KIN	50.	DUG

MODIFIED RHYME TEST

TALKER'S LIST

FORM 2

"Number _____ is _____."

1.	CUSS	26.	SAW
2.	FIN	27.	SILL
3.	LAME	28.	NEAT
4.	GAME	29.	TOT
5.	SHOP	30.	SEEK
6.	BARK	31.	BILL
7.	HEAP	32.	LIP
8.	PIT	33.	REST
9.	WED	34.	COLD
10.	MAD	35.	TICK
11.	BATH	36.	HANG
12.	TEAK	37.	PEACH
13.	EEL	38.	DUST
14.	RAY	39.	SAME
15.	SAT	40.	DIN
16.	MEN	41.	BUG
17.	SUNG	42.	FIG
18.	CASE	43.	PAVE
19.	FIT	44.	TAP
20.	SENT	45.	BEAK
21.	PUB	46.	PAN
22.	PALE	47.	HIT
23.	LOOK	48.	RUN
24.	SOIL	49.	PAY
25.	KILL	50.	DUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 3

"Number _____ is _____."

1.	CUFF	26.	LAW
2.	TIN	27.	SIN
3.	LAY	28.	HEAT
4.	CAME	29.	NOT
5.	POP	30.	SEETHE
6.	MARK	31.	KILL
7.	HEAL	32.	TIP
8.	PIP	33.	WEST
9.	RED	34.	HOLD
10.	MATH	35.	SICK
11.	BACK	36.	GANG
12	TEASE	37.	PEAK
13.	FEEL	38.	RUST
14.	RACE	39.	SAVE
15.	SAG	40.	DID
16.	DEN	41.	BUT
17.	SUB	42.	BIG
18.	CANE	43.	PACE
19.	FIN	44.	TAM
20.	WENT	45.	BEAT
21.	PUP	46.	PACK
22.	TALE	47.	FIT
23.	SHOOK	48.	GUN
24.	BOIL	49.	SAY
25.	KID	50.	DUNG

MODIFIED RHYME TEST

TALKER'S LIST

FORM 4

"Number _____ is _____."

1.	CUT	26.	RAW
2.	PIN	27.	SING
3.	LATE	28.	MEAT
4.	FAME	29.	HOT
5.	TOP	30.	SEEP
6.	HARK	31.	WILL
7.	HEAR	32.	SIP
8.	PILL	33.	NEST
9.	LED	34.	SOLD
10.	MAP	35.	KICK
11.	BAT	36.	RANG
12.	TEACH	37.	PEACE
13.	PEEL	38.	BUST
14.	RAVE	39.	SAKE
15.	SAD	40.	DIG
16.	TEN	41.	BUN
17.	SUD	42.	DIG
18.	CAME	43.	PAGE
19.	FILL	44.	TAB
20.	TENT	45.	BEAN
21.	PUN	46.	PASS
22.	GALE	47.	KIT
23.	BOOK	48.	SUN
24.	FOIL	49.	WAY
25.	KICK	50.	DUCK

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you <u>hear</u>.

1.	CUFF	CUSS	CUP	6.	LARK	BARK	PARK
	CUD	CUT	CUB		MARK	DARK	HARK
2.	WIN	DIN	PIN	7.	HEAL	HEATH	HEAP
	TIN	SIN	FIN		HEAVE	HEAR	HEAT
3.	LACE	LAKE	LATE	8.	PIN	PILL	PIP
	LAME	LANE	LAY		PICK	PIG	PIT
4.	FAME	NAME	SAME	9.	FED	SHED	LED
	GAME	CAME	TAME		RED	WED	BED
5.	TOP	COP	POP	10.	MAD	MAT	MATH
	HOP	SHOP	MOP		MAN	MAP	MASS

FORM 1 - Page 1

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

11.	BAT	BAN	BATH	16.	TEN	DEN	THEN
	BASS	BAD	BACK		MEN	HEN	PEN
12.	TEAL	TEASE	TEACH	17.	SUN	SUNG	SUM
	TEAK	TEAM	TEAR		SUP	SUD	SUB
13.	REEL	KEEL	PEEL	18.	CAPE	CAKE	CANE
	EEL	HEEL	FEEL		CASE	CAME	CAVE
14.	RATE	RAKE	RAY	19.	FILL	FIN	FIG
	RACE	RAVE	RAZE		FIB	FIT	FIZZ
15.	SAG	SAP	SASS	20.	BENT	SENT	RENT
	SAD	SACK	SAT		WENT	DENT	TENT

FORM 1 - Page 2

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

21.	PUP	PUN	PUS	26.	PAW	LAW	SAW
	PUB	PUFF	PUCK		THAW	JAW	RAW
22.	PALE	SALE	BALE	27.	SICK	SIP	SIN
	GALE	MALE	TALE		SING	SILL	SIT
23.	COOK	BOOK	HOOK	28.	HEAT	NEAT	MEAT
	SHOOK	TOOK	LOOK		SEAT	BEAT	FEAT
24.	OIL	TOIL	FOIL	29.	POT	LOT	TOT
	BOIL	SOIL	COIL		HOT	NOT	GOT
25.	KILL	KIN	KID	30.	SEEN	SEEM	SEED
	KICK	KING	KIT		SEETHE	SEEK	SEEP

FORM 1 - Page 3

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you <u>hear</u>.

31.	KILL	TILL	HILL	36.	HANG	RANG	FANG
	BILL	WILL	FILL		GANG	SANG	BANG
32.	RIP	HIP	LIP	37.	PEAK	PEAT	PEAL
	DIP	SIP	TIP		PEACH	PEAS	PEACE
33.	WEST	TEST	REST	38.	GUST	DUST	MUST
	BEST	NEST	VEST		RUST	BUST	JUST
34.	COLD	HOLD	FOLD	39.	SAFE	SANE	SAVE
	SOLD	GOLD	TOLD		SAME	SAKE	SALE
35.	KICK	LICK	SICK	40.	DIN	DIP	DILL
	TICK	PICK	WICK		DID	DIM	DIG

FORM 1 - Page 4

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

41.	BUCK	BUG	BUFF	46.	PACK	PAD	PATH
	BUS	BUN	BUT		PAT	PAN	PASS
42.	BIG	PIG	DIG	47.	WIT	HIT	FIT
	RIG	FIG	WIG		BIT	SIT	KIT
43.	PAVE	PACE	PAY	48.	GUN	SUN	FUN
	PALE	PANE	PAGE		RUN	NUN	BUN
44.	TANG	TACK	TAP	49.	SAY	WAY	MAY
	TAN	TAB	TAM		DAY	PAY	GAY
45.	BEAD	BEAN	BEAT	50.	DUN	DUNG	DUD
	BEAK	BEACH	BEAM		DUCK	DUG	DUB

FORM 1 - Page 5

APPENDIX D

DESCRIPTIONS AND INSTRUCTIONS FOR BODY MOBILITY AND PSYCHOMOTOR TASKS

APPENDIX D. Descriptions and Instructions for Body Mobility and Psychomotor Tasks

1. <u>Standing Trunk Flexion.</u>[32]

a. <u>Materials</u>: A metric ruler.

b. <u>Instructions to tester</u>: Read the instructions to the subject. Read them word for word. Do not change or add to them.

<u>Scoring</u>: Measure the maximal point to which the subject's fingertips reach when the movement is performed. The ruler is placed perpendicular to the floor and the distance is measured from the floor to the subject's fingertips. Four successive trials are administered with 15-sec intervals between trials. The score is the mean of the four trials.

c. <u>Instructions to be read to the subject</u>:

(1) Stand erect with your feet parallel, about four inches apart. Keep your knees stiff and do two preliminary toe touches, that is, bend at the waist and reach down as far as possible each time. Do a third toe touch, keeping your hands together, and holding that position for a few seconds.

(2) Are there any questions? (Correct the subjects if they are not following instructions.)

2. Upper Arm Abduction.[33]

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the gonimometer on the right arm just above the elbow with the dial on the posterior side of the arm. Set the goniometer to zero. Be sure that the subject is standing with toes, abdomen, sternum, and nose against the projecting corner of a wall. Watch for contact with the wall, extension of the back, arm rotation, elbow flexion, and movement out of the frontal plane. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Start facing the corner with toes, abdomen, sternum, and nose against the corner of the wall, arms hanging at your sides, palms facing in toward the body. (Set the goniometer to zero.)

(2) Raise both arms sideward and upward as far as possible while maintaining contact with the wall.

(3) Are there any questions? (Correct the subjects if they are not following the instructions.)

3. Upper Arm Forward Extension.[34]

a. Materials: Goniometer.

b. Instructions to the tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right arm just above the elbow with the dial on the lateral surface. Be sure that the subject is standing with his arm against his side, elbow stiff, and the arm perpendicular to the floor. Set the goniometer to zero. Read the goniometer when the arm is raised as far forward and up as possible. The elbow is kept stiff and the arm parallel to the median plane. The trunk is maintained erect. There are four trials with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand facing the wall but not quite touching it. Your right shoulder and arm should be just past the edge of the doorway.

(2) Place your right arm against your side with the elbow stiff and the arm straight down. (Set goniometer to zero.)

(3) Now raise your entire arm forward and up as far as possible. Keep your elbow stiff and stand up straight.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

4. Upper Arm Backward Extension.[24]

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands erect with the back against a wall. The entire arm, elbow stiff, is rotated until the palm of the hand faces outward and the thumb points dorsally. The goniometer is placed on the right arm just above the elbow and is set to zero when the arm is perpendicular to the floor. The subject extends the entire arm backward as far as possible while keeping the elbow stiff and the palm out. Read the goniometer when the limit of motion is reached, when the elbow bends, or when the arm moves out of the medial plane. There are four trials with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand with your back to the wall. Your right shoulder and arm should be just past the edge of the doorway.

(2) Place your right arm against your side with the elbow stiff and the arm straight down. Rotate your arm until your palm faces outward. (Set the goniometer to zero.)

(3) Now raise your entire arm backward as far as possible. Keep your elbow stiff and your palm out.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

5. Upper Leg Flexion.[24]

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the lateral surface. The subject stands erect with the back against a wall and feet together. Set the goniometer to zero. Read the goniometer when the right upper leg is raised as far up as possible. The right leg is allowed to bend freely at the knee. An upright support is grasped with the left hand to maintain balance. There are four trials with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand erect with your feet together and your back against this wall. Grasp the support with the left hand. (Set the goniometer to zero.)

(2) Raise your upper leg up as far as possible. Let your lower leg bend freely at the knee. Keep your left knee stiff and your back against the wall.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

6. Upper Leg Forward Extension.[26]

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the lateral surface. The subject stands erect with the back against a wall and feet together. Set the goniometer to zero. Read the goniometer when the right leg is raised as far forward and up as possible. The knee is kept stiff and the back is kept against the wall. An upright support is grasped with the left hand to maintain balance. There are four trials with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand erect with your feet together and your back against the wall. Grasp the support with your left hand. (Set the goniometer to zero.)

(2) Raise your leg forward and up as far as possible. Keep your knees stiff and your back against the wall.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

7. Upper Leg Abduction.[24]

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the posterior side of the leg. Be sure that the subject is standing erect, feet together, and facing an upright support. The subject grasps the support firmly with both hands. Set the goniometer to zero. Watch for bending of the trunk and leg rotation. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Start facing the support and about one foot from it. Stand erect with your feet together and grasp the support with both hands. (Set the goniometer to zero.)

(2) Raise your right leg sideward and up as far as possible being careful not to bend your trunk or rotate your leg. Also, keep your knee stiff.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

8. Upper Leg Backward Extension.[34]

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring. Place the goniometer on the lateral surface of the right leg just above the knee. Be sure that the subject is standing erect, feet together, and facing an upright support. The subject stands approximately one foot away from the support, grasping it with both hands and with the right hip and leg partially extended beyond it. Set the goniometer to zero. Read the goniometer when the right leg is raised as far backward as possible. There are four trials with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand facing the support and about one foot from it. Stand erect with your feet together, your right foot just beyond the support, and grasp it with both hands. (Set the goniometer to zero.)

(2) Now move your right leg as far backward as possible. Hold that position.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

9. Ventral-Dorsal Head Flexion.[34]

a. Materials: Goniometer and straight-back chair.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on the right lateral surface of the head and is zeroed when the subject's head is forward and down in a ventral position. The shoulders remain against the back of the chair. The head is then tilted as far back as possible (dorsal position) and the displacement of the head from the zero position is read in degrees. Four trials are given with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Sit upright in the chair with your hands clasped behind the chair. Try not to move your chest or shoulders.

(2) When I tell you, bend your head as far down as possible without moving your chest or shoulders. Hold this position for five seconds. (Set the goniometer to zero.)

(3) Now bend your head as far back as possible without moving your shoulders or chest. Hold this position for five seconds.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

10. Head Rotation.[34]

a. Materials: Goniometer and straight back chair.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on the cranial surface (top) of the head and is zeroed when the subject has rotated his head as far as possible to the left. It is read when the subject has rotated his head as far as possible to the right. Four trials are given with 15-sec intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand straight and then bend at the waist until your chest and head are parallel to the floor. Grasp the seat of the chair to hold yourself that way.

(2) Turn your head to the left, as far as it will go, and then hold it. (Set the goniometer to zero.) Now turn your head to the right, as far as it will go, and hold it.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

11. Pursuit Rotor.[35]

a. Materials: A turntable 25.5 cm (10.04 in.) in diameter, with a circular target disc, 1.9 cm (0.75 in.) in diameter, embedded in the turntable surface, and a stylus with a tip 0.3 cm (0.12 in.) in diameter. The Lafayette Rotary Pursuit, Model 30012, was used in this study. The task components are located on top of a table.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands and holds the stylus in the preferred hand. While the turntable is revolving at 60 rev/min, the subject is to track the moving target by keeping the stylus in contact with the target disc. The score is the total number of seconds over four, 30-sec trials that the stylus is in contact with the target. There are 30-sec rest intervals between trials.

c. Instructions to be read to the subject:

(1) Hold the stylus in your preferred hand and position it just above the turntable.

(2) When the turntable begins to move, place the tip of the stylus on the moving target and move the stylus in order to keep it in contact with the target.

(3) Your score is the total amount of time that you keep the stylus on the target during four trials of 30 sec each.

(4) The trial will start when the turntable begins to move. The trials will stop when the turntable stops moving.

(5) Are there any questions?

(6) Begin tracking as soon as the turntable moves.

12. O'Connor Finger Dexterity Test.[36]

a. Materials: Pegboard equipped with pins and located on a table. The pins are 2.5 cm (0.98 in.) long and 0.1 cm (0.04 in.) in diameter. Each hole in the pegboard is 0.5 cm (0.20 in.) in diameter.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring. The time required to place three pins in each of 20 holes is the subject's score. The subject stands while doing the task and can use only one hand.

c. Instructions to be read to the subject:

(1) Begin with your preferred hand on the table alongside the board.

(2) On the "Go" signal, pick up as many as three pins with your preferred hand and place them in a hole on the board. Continue picking pins up, no more than three at a time, and dropping them into holes until there are three pins in every hole. You may use only your preferred hand for this task. If you pick up more than three pins at one time, or if you drop more than three pins in a hole, you must return the extra pins to the dish before using them. Do not use any excess pins dropped on the board to fill the holes unless they are placed back into the dish first.

(3) Your score is the time required to put three pins in every hole.

(4) Are there any questions? Ready? Set? Go. (Correct the subjects if they are not following instructions.)

13. Purdue Pegboard Assembly Test.[37]

a. Materials: Pegboard equipped with pins, collars, and washers located on a table.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The time required to complete the construction of 12 pin-washer-collar-washer assemblies is the subject's score. The subject performs the task while standing.

c. Instructions to be read to the subject:

(1) Begin with your hands on the table alongside the board.

(2) On the "Go" signal, pick up one pin from the right-hand cup with your right hand and, while placing it in the top hole in the right-hand column, pick up a washer with your left hand. As soon as the pin has been placed, drop the washer over the pin. While the washer is being placed over the pin with the left hand, pick up a collar with the right hand. While the collar is being dropped over the pin, pick up another washer with the left hand and drop it over the collar. This completes the first assembly consisting of a pin, a washer, a collar, and a washer.

(3) As the final washer for the first assembly is being placed with the left hand, start the second assembly immediately by picking up another pin with the right hand. Place it in the next hole in the column, drop a washer over it with the left hand; then a collar with the right hand, and so on, completing another assembly. Keep both hands busy, always picking up pins and collars with the right hand and washers with the left hand.

(4) Your score is the time required to complete 12 assemblies.

(5) Are there any questions? Ready? Set? Go. (Correct the subjects if they are not following instructions.)

14. Railwalk.[38]

a. Materials: A rail 365 cm (143.70 in.) and 1.90 cm (0.75 in.) thick, marked at intervals of 1 cm (0.39 in.).

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Record to the nearest 1 cm the distance walked before a foot touches the support of the rail or the floor. Walking must be heel to toe and the subjects must keep their hands grasped behind their backs.

c. Instructions to be read to the subject:

(1) Stand at the end of the board, ready to begin walking. Start by placing one foot on the board so that the back of the foot is even with the end of the board. Then place your other foot in front of the first so that the heel touches the toe of the first foot. Walk as far as you can in this fashion, heel to toe. Grasp your hands behind your back for this test.

(2) Your score will be the distance to the end of the toe of the last foot that remained on the rail.

(3) Any questions? Begin.

APPENDIX E

CLOTHING AND PERFORMANCE QUESTIONNAIRE

APPENDIX E. Clothing and Performance Questionnaire

CHEMICAL PROTECTIVE CLOTHING PERFORMANCE QUESTIONNAIRE

Name: ______________________ Clothing Condition: ______________________

Section Ia. Individual Movement Performance

For each movement, indicate how much the clothing worn in the present condition seemed to hinder your performance. Circle the appropriate vertical line.

	not at all	slightly	moderately	considerably	extremely
1. Standing Trunk Flexion	0	1	2	3	4
2. Sitting Trunk Flexion	0	1	2	3	4
3. Upper Arm Abduction	0	1	2	3	4
4. Upper Arm Forward Extension	0	1	2	3	4
5. Upper Arm Backward Extension	0	1	2	3	4
6. Upper Leg Flexion	0	1	2	3	4
7. Upper Leg Forward Extension	0	1	2	3	4
8. Upper Leg Abduction	0	1	2	3	4

	not at all	slightly	moderately	considerably	extremely
9. Upper Leg Backward Extension	0	1	2	3	4
10. Head Flexion	0	1	2	3	4
11. Head Rotation	0	1	2	3	4

CHEMICAL PROTECTIVE CLOTHING PERFORMANCE QUESTIONNAIRE

Name: ______________________ Clothing Condition: ____________________

Section Ib. Individual Task Performance

For each task, indicate how much the clothing worn in the present condition seemed to impair your performance. Circle the appropriate vertical line.

	not at all	slightly	moderately	considerably	extremely
1. Pursuit Rotor	0	1	2	3	4
2. O'Connor Five Finger	0	1	2	3	4
3. Pegboard Assembly	0	1	2	3	4
4. Railwalk	0	1	2	3	4

Name: ______________________ Clothing Condition: ______________________

Section II. Importance of Design Characteristics — pg.1

Rate each of the design characteristics listed below to show how important they were in interfering with the movements or tasks performed in the present condition. Put an 'X' in the appropriate space.

Design Characteristics	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
1. Garment bulk					
2. Garment weight					
3. Collar flexibility					
4. Collar height					
5. Shoulder flexibility					
6. Armhole opening fit					
7. Sleeve cuff flexibility					
8. Sleeve length					
9. Sleeve cuff fit					
10. Chest flexibility					
11. Waist flexibility					
12. Waist fit					
13. Trouser length at crotch					
14. Upper leg fit					
15. Fit at knee					
16. Lower leg fit					
17. Trouser leg length					
18. Ankle flexibility					

Name: ______________________ Clothing Condition: ______________________

Section II. Importance of Design Characteristics — pg.2

Design Characteristics	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
19. Glove thickness					
20. Glove flexibility					
21. Glove finger lengths					
22. Glove slipperiness					
23. Overboot flexibility					
24. Overboot bulk					
25. Overboot weight					
26. Overboot sole slipperiness					
27. Overboot protruding parts					
28. Hood flexibility					
29. Hood bulk					
30. Hood protruding parts					
31. Mask weight					
32. Mask protruding parts					
33. Mask lens size					
34. Mask lens shape					
35. Mask lens clarity					

Name: ______________________ Clothing Condition: ______________________

Section III: Problems with Clothing Items

Rate each of the problems listed below to show how important they were in <u>interfering</u> with or <u>impairing</u> your performance on the movements/tasks in the present condition.

Clothing Item	Problems	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
Garment (Overgarment, BDU, or shorts)	a. bulky					
	b. rubbing					
	c. heavy					
	d. hot					
	e. loose					
	f. stiff					
	g. sweaty					
	h. binding					
	i. bunching up					
	j. tight					
	k. riding up					

Comments (additional problems,etc.):

Name: ______________________ Clothing Condition: ______________________

Section III. Problems with Clothing Items, cont. (p.2)

Rate each of the problems listed below to show how important they were in interfering with or impairing your performance on the movements/tasks in the present condition.

Clothing Item	Problems	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
Chemical Protective Mask	a. rubbing					
	b. heavy					
	c. hot					
	d. loose					
	e. binding					
	f. tight					
	g. sweaty					
	h. pressure					
	i. digging in					
	j. pinching					
	k. slipping					
	l. blocking vision					
	m. snagging					
	n. unbalanced					
	o. breathing resistance					

Comments (additional problems, etc.):

Name: ______________________ Clothing Condition: ______________

Section III: Problems with Clothing Items, cont. (p.3)

Rate each of the problems listed below to show how important they were in interfering with or impairing your performance on the movements/tasks in the present condition.

Clothing Item	Problems	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
Chemical Protective Hood	a. rubbing					
	b. hot					
	c. loose					
	d. pressure					
	e. binding					
	f. tight					
	g. sweaty					
	h. pinching					
	i. slipping					
	j. blocking vision					
	k. snagging					
	l. pulling					
	m. bunching up					

Comments (additional problems, etc.):

Name: ______________________ Clothing Condition: ______________

Section III: Problems with Clothing Items, cont. (p.4)

Rate each of the problems listed below to show how important they were in interfering with or impairing your performance on the movements/tasks in the present condition.

Clothing Item	Problems	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
Chemical Protective Gloves	a. bulky					
	b. rubbing					
	c. hot					
	d. loose					
	e. stiff					
	f. sweaty					
	g. tight					
	h. pressure					
	i. pinching					
	j. slipping					
	k. snagging					
	l. bunching up					
	m. impaired feel					

Comments (additional problems, etc.):

Name: ______________________ Clothing Condition: ______________________

Section III: Problems with Clothing Items, cont. (p.5)

Rate each of the problems below to show how important they were in interfering with or impairing your performance on the movements/tasks in the present condition.

Clothing Item	Problems	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERATE IMPORTANCE	OF EXTREME IMPORTANCE
Chemical Protective Overboots	a. bulky					
	b. heavy					
	c. hot					
	d. loose					
	e. stiff					
	f. sweaty					
	g. tight					
	h. pressure					
	i. pinching					
	j. slipping					
	k. snagging					
	l. impaired feel					

Comments (additional problems, etc.):

Name: ______________________ Clothing Condition: ______________

Section IV: Dimensions for Total Clothing Ensemble

Indicate your opinion, whether neutral, positive, or negative, on each of the following dimensions. Circle the appropriate vertical line.

While performing the movements/tasks, I found all of the items I have on to be:

		extremely -3	very -2	somewhat -1	neutral 0	somewhat +1	very +2	extremely +3	
1.	uncomfortable	|	|	|	|	|	|	|	comfortable
2.	inflexible	|	|	|	|	|	|	|	flexible
3.	heavy	|	|	|	|	|	|	|	light
4.	binding	|	|	|	|	|	|	|	free-moving
5.	hot	|	|	|	|	|	|	|	cool
6.	poorly balanced	|	|	|	|	|	|	|	well-balanced
7.	tight	|	|	|	|	|	|	|	loose

extremely	very	somewhat	neutral	somewhat	very	extremely
-3	-2	-1	0	+1	+2	+3

8. flimsy — sturdy

9. poorly-fitted — well-fitted

10. hard to work in — easy to work in

11. While performing the movements/tasks, I found all the items I have on to function together:

extremely	very	somewhat	neutral	somewhat	very	extremely
-3	-2	-1	0	+1	+2	+3

poorly — well

12. In general, my attitude toward all the clothing items I have is:

extremely	very	somewhat	neutral	somewhat	very	extremely
-3	-2	-1	0	+1	+2	+3

dislike — like

Name: ______________________ Clothing Condition: ______________

Section V: Clothing Item Selection

Which one of the clothing items produced the greatest interference with the movements/tasks performed? Place an 'X' in the appropriate space.

Battle Dress Uniform	____
Overgarment	____
Mask	____
Hood	____
Overboots	____
Gloves	____
Shorts and T-shirt	____
Combat boots	____